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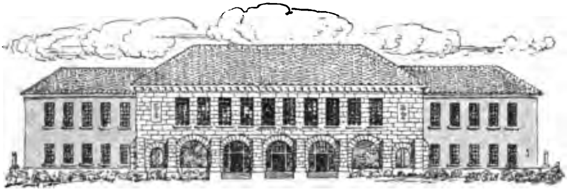
HANDBOOK OF SIMPLE EXPERIMENTS IN PHYSIOLOGY

BY
CHARLES · H · STOWELL

AUTHOR · OF
THE · HEALTH · SERIES
OF · SCHOOL
PHYSIOLOGIES



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A HANDBOOK
OF
SIMPLE EXPERIMENTS
IN
PHYSIOLOGY

Illustrated with Original Sketches

BY

CHARLES H. STOWELL, M.D.

Late Professor of Histology and Microscopy, and Assistant Professor of Physiology, University of Michigan;

AUTHOR OF "STUDENTS' MANUAL OF HISTOLOGY," "MICROSCOPICAL DIAGNOSIS," "THE STRUCTURE OF TEETH," "ESSENTIALS OF HEALTH," "A HEALTHY BODY," "A PRIMER OF HEALTH," EDITOR OF "THE NATIONAL MEDICAL REVIEW," "PRACTICAL MEDICINE," ETC.

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PREFACE.

PHYSIOLOGY, although a laboratory study, presents unusual difficulties in demonstration. Physiological experiments are often surrounded by such a variety of conditions that it is quite impossible to distinguish clearly between cause and effect.

The experiments recorded here have been carefully chosen. They include none that either involve doubtful and obscure elements or require for their proper performance a complicated outfit. Only those have been selected with which the author is perfectly familiar, and which are especially adapted to demonstrate the teachings of the Health Series of School Physiologies. While the list is by no means complete, it is at least suggestive.

The author appreciates full well the embarrassment under which teachers labor in presenting subjects so unfamiliar as anatomy, physiology, and hygiene. It is with the hope of aiding in the solution of some of the teacher's problems, and of making experimental work in physiology less difficult, that this little volume has been prepared.

C. H. S.

December, 1896.

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A HANDBOOK

OF

SIMPLE EXPERIMENTS IN PHYSIOLOGY.

INTRODUCTION.

THE CLAIMS OF PHYSIOLOGICAL STUDY.

The child who is well-born has the best of prospects for a successful life. This is not the birthright which comes from wealth or high position. It is the inheritance of a sound constitution.

Resistive Power. It is a conservative estimate, based on a large number of statistics, that one-third of all children die before they reach their fifth year. Many die simply because they do not have that amount of resistive power which should be the heritage of every child. As a result, some slight disturbance, as of the digestive system, is sufficient to prove fatal. The physician often has occasion to remark that his little patient "is making a strong fight for life;" in other words, the child is exhibiting great power in resisting disease. This ability to overcome the diseases so prevalent during infancy and early childhood is often a question of inheritance. With this understanding of the case, the doctrine of heredity stands forth more prominently than ever.

Tendency to Disease. There are a number of diseases which may not be hereditary in the strict interpretation of that term, and yet the tendency to them is generally recognized as transmissible from parent to child. Life-insurance companies understand this well, and in the directions given to their medical examiners they state that no applicant should be recommended "where both parents have died of phthisis; where one parent died of phthisis and where one or more brothers or sisters have died of phthisis; where two cases of apoplexy or paralysis have occurred in the family; where two cases of heart disease, or two of insanity, or two of Bright's disease, or two of cancer have occurred in the family." Here, again, is additional evidence of the importance of the question of heredity.

Love for Strong Drink Inherited. Intemperance produces unsoundness of body and mind, weaknesses which are certainly transmissible. The young man who has inherited a tendency to the use of strong drink finds himself unequal to resist a temptation which makes no impression upon a strong, evenly balanced associate who has inherited a constitution free from such infirmities.

Importance of Good Health. The greatest factor in the production of domestic happiness, social, literary, and business success, just laws, and general morality is good health. Persons born with weak constitutions may do much to overcome this deficiency, but they can never fully remedy it. The teacher of physiology and hygiene in the public schools does not expect in his lifetime to see the full results of his teaching. He is contented to wait until the children of to-day have children of their own pursuing the same study. When another and a wiser generation shall appear, it need then no longer be true that "one-third of all children die before they reach their fifth year."

This is not advocating the development of a man for the value of his muscles alone. It is taught because it is true that good health is a necessary factor in bringing forth the highest and best results of our existence.

Hygiene and Morals. The usefulness of a lifetime may be greatly impaired because a few simple physiological laws were not early applied. A child may be deprived of its necessary amount of sleep, or it may be given indigestible or too highly seasoned food. As a result, it becomes fretful and petulant. The aches and pains, together with the ill temper, make home government less strict, and the child grows up wilful and refractory. Neither tender appeals nor stern commands prevent a wayward course.

Results. The children of to-day, the future fathers and mothers, are being instructed in the structure and uses of the body and in the methods by which health is preserved. With these teachings in mind, they will grow to manhood and womanhood with better knowledge of the conditions necessary to correct living. They will not only be able to impart to their children stronger minds and healthier bodies, but they will also understand more clearly how to care for and instruct them. Therefore, as a result of the teaching of anatomy, physiology, and hygiene in the public schools there is every reason to believe that the coming generations will far exceed the present in moral, mental, and physical vigor.

CHAPTER I.

PRELIMINARY HINTS TO THE TEACHER.

Physiology occupies a unique place among the sciences now so universally taught in our elementary and secondary schools. Though properly a biological study, it is closely allied to the chemico-physical sciences, for it is largely based upon experiment and investigation rather than upon analysis and classification. Viewed from the practical side, it is peculiar in that it enters the domain of morals, furnishing deductions from its principles which indicate the course of action which should or should not be followed by the individual.

Adaptation to Grade. - How to adapt so complex a science to the comprehension of primary and grammar grade pupils is a problem which confronts the teacher at the outset. This problem the author has carefully considered in all its bearings. In each book of The Health Series an effort is made to present only such phases of the subject as are suited to the mental development of the grade of pupils for which the book is intended.

In primary schools the instruction is best given in short observation lessons on the parts of the body and their uses, together with short talks by the teacher on the general care of the body and simple rules regarding right living. The body should be studied as a whole, not as revealed by dissections. It is estimated that if the work is thus planned there will be material enough for fully three years, especially if "A Primer of Health" is used here as a supplementary reader. In the fourth year of school life this book may be advantageously placed in the pupil's hands as a text-book, devoting to it one or more lessons a week throughout the year. If this work is varied with simple experiments and illustrative lessons, the book will not usually be completed before the close of the fifth year.[1]

"A Healthy Body" would then be taken up in the sixth and seventh years of school life. By giving one lesson a week or its equivalent, the work can be completed by the close of the seventh year.

In the eighth and ninth school years the pupil will be well prepared to take up the last book of the series, "The Essentials of Health." The author also had in mind the adaptation of this book to the first year of the high school, where it can be used in connection with systematic laboratory work. As it does not presuppose a knowledge of chemistry and physics, it is especially well adapted to use at this time of school life.

References. In addition to copies of the text-books used by pupils, every progressive teacher feels the need of a few reference books which give a more elaborate presentation of the subject. There are a large number of works on anatomy and physiology which might be recommended and from which it is difficult to make any selection. There are also many works devoted to special phases of the subject which will be of great importance to the teacher. A few carefully selected reference books are given at the close of the chapter, although the list is far from complete.

---

[1] Classes which can complete "A Primer of Health" before the close of the fifth year will be fully prepared to take up "A Healthy Body" before the beginning of the sixth year. The books of the series are so carefully graded that a pupil who has mastered one book will have no difficulty in taking up the next.

Laboratory Work. Fortunately a large amount of apparatus is not required in order to illustrate the statements in the text-books. If the study is pursued during the first year of the high school, practical, individual work can be developed to a high degree. Fine dissections of the arterial, muscular, and nervous systems can be made from specimens procured at the market, or from such small animals as the rabbit or squirrel. Here the study can also be made most interesting by dissections of the heart and eye of the ox and the brain of the sheep. Sections can be made of bones and teeth, and the study of ligaments and joints can be made clear by careful dissections.

While engaged in this practical study, the teacher will need to guard against the tendency of the pupil to emphasize too strongly the structure of the body to the neglect of the study of its function and the conditions under which health is maintained. For instance, the structure of the heart is intensely interesting; but we must keep in mind its function, and what an important part it plays in the maintenance of health. Specimens of bones always engage attention; but their proper growth and development, and the maintenance of correct positions of the body while the bones are forming, must not be neglected.

No attempt has been made to grade these experiments;

the teacher can readily select from the entire number such as are best adapted to the particular grades. Below the high school it is not expected that all the experiments will be performed in any one year. If time is an important element, and it usually is, then a portion of the time ordinarily devoted to the text-book work may be occupied by experiments. Such a substitute increases the interest and intelligent attention of the pupils. The best teaching links together the text-book and laboratory work wherever that is possible. The pupil must be made to see the connection of the experiment with the fact stated in his text-book. He should be made to see clearly that when oxygen is taken into the blood from the lungs, and when the chyle is absorbed into the system, the work is yet far from complete. The first chapter in "The Essentials of Health" was written especially to make such subjects more clear. Reference should frequently be made to it. It teaches that the most marvellous work is the change of the oxygen and chyle, food elements, into muscle, nerve, bone, etc. It also teaches that these changes do not occur either in the lungs, the stomach, or the liver, but in each individual cell of the body.

Use of the Microscope. It is the study of physiology from this standpoint that has made the microscope of such inestimable value. The text-book may declare that each drop of blood contains many millions of red corpuscles, yet none of us can comprehend such vast figures. But let the pupil see that the slightest stain of blood on a piece of glass, examined by the microscope, shows countless numbers of these bodies; and for the first time he receives something like a proper appreciation of their vast numbers and their importance. The text-book may declare that bone is a living tissue; yet the pupil cannot understand it until he has seen, by aid of the microscope, what a great proportion of bone is occupied by the bone cells, — living matter.

Henry Baker knew something of the revelations which the magnifying-glass affords. In 1742 he wrote: "The microscopist never can feel his time hang heavy on his hands, or be weary of himself, for wanting to know how to employ his thoughts; since every animal, flower, fruit, or insect — nay, almost every particle of matter — affords him an entertainment; each garden or field is to him a cabinet of curiosities, every one of which he longs to examine fully; and he considers the whole universe as a magazine of wonders, which infinite ages are scarce sufficient to contemplate and admire enough."

Performing Experiments. The teacher should allow the pupil to enter into the work of the experiments as largely as possible. Let the pupil add the vinegar to the milk, and then describe what has occurred. Let the pupil look for the valves in the heart of the sheep which he has procured at the market, and be sure he recognizes them. The experiments in this Handbook are generally so simple that no difficulty will be experienced in performing them. A few, however, require some preparation.

Preparing Specimens. If care is taken to remove the appearance of blood from any specimen of flesh, as the heart, muscles, etc., a large part of all objection which any sensitive pupil might have will be removed. By allowing these specimens to remain in cold water over night, or a few hours even, the blood can be nearly all removed. It is also better, before bringing specimens into the class-room, to remove any superfluous tissue, as fat, etc., thus making the specimen as neat as possible. Then, by the use of a towel, the organs or tissues can be presented in an unobjectionable manner. In preparing the lungs, it is only necessary to wash the exterior in water, using care not to let any of the water enter the trachea. Of course, if a laboratory is provided for this work, such preparation is unnecessary. No instruments are necessary with the exception of a knife, forceps, and scissors. The knife should have the blade firmly set in the handle, with its cutting edge convex.

Note-Books. There is no better method of fixing in the minds of pupils the results of their own work than the free use of a note-book. If one page of the note-book is used for sketching what the pupil observes in his experiments and observations, and the opposite page for recording his descriptions and conclusions, close and accurate observation will be taught at the same time that the facts are being permanently fixed in the mind. If colored pencils are used, the interest can often be increased.

Reference Books: —

"Anatomy," Gray.
"Physiology," Flint.
"Practical Physiology," Stirling.
"First Aids in Illness and Injury," Pilcher.
"Text-Book of Hygiene," Rohé.
"Fermentation," Schutzenberger.
"Principles of Bacteriology," Abbott.

CHAPTER II.

FOODS.[1]

THE number of experiments which can be performed to illustrate Foods and their Uses is very great, and the ingenuity of the teacher has here a wide opportunity for exercise.

1. **Water, Large Amount in Foods.** (*Materials: Two potatoes of equal size.*) This may be illustrated by taking two potatoes of equal size. Place one in the oven, and let it remain there until it is over-baked, and so more completely dried. Take the raw and baked potatoes to school, and ask the pupils to note the differences in weight. The baked potato is light from loss of water.

2. **Milk, Composition of.** (*Materials: Glass of water, teaspoonful of butter, pulverized chalk, cheese, piece of cooked white of egg, a few grains of sugar.*) Nearly fill a glass with water; place by its side a teaspoonful of butter, a few grains of pulverized chalk, a piece of cheese, a small piece of the cooked white of an egg, and a few grains of sugar, the "sugar of milk" preferred. These represent the water, oil, mineral matter, casein, albumen, and sugar which compose milk.

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[1] The Essentials of Health, pp. 17–39; A Healthy Body, pp. 60–69; A Primer of Health, pp. 7–19.

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3. **Why Cream rises.** (*Materials: Glass of water, teaspoonful of sweet oil, piece of butter.*) Add a teaspoonful of any oil, as sweet oil, to a glass of water. The oil will rise to the top at once. Place the piece of butter in the glass of water; it also comes to the top. Let pupils draw an inference as to the reason why cream comes to the top of the milk.

4. **Casein.** (*Materials: Glass of milk, a few drops of strong vinegar, skimmed milk.*) Add a few drops of acetic acid or strong vinegar to a glass of milk: the milk quickly curdles. The curdled, coagulated mass is the casein. When properly treated and pressed into form, casein makes cheese.

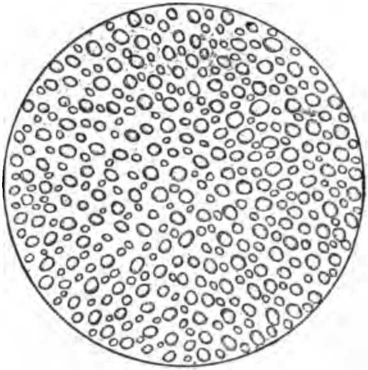

FIG. 1. — Appearance of milk under the microscope, showing the oil as distinct globules.

Add a few drops of vinegar or acetic acid to some skimmed milk. The milk curdles as before; showing that the presence or absence of the cream, or oil, of the milk has nothing to do with this change.

5. **Butter.** (*Materials: Water, flour, mixing-dish, spoon.*) Make a number of balls of stiff dough, as large as marbles. Call attention to the fact that the microscope shows that the fat of milk exists in the form of minute round bodies. Roll the balls of dough about, and gradually mix them into one mass. This operation represents the process of churning; which is simply

beating the minute oil globules into one mass, ca
butter.

6. Connective Tissue — Animal Gelatine. (
Piece of lean, uncooked meat, fatty tissue.)
piece of lean meat parallel to the course of th
i. e., with the grain. All of the r d h can
in this way. The tough, stringy
the connective tissue which binds the
fibres together. It is a representative of a
tive tissues of the body. It is widely distr
parts together and forming the strong te

After prolonged boiling this connectiv
nearly all dissolve, and upon cooling wil
It is then called animal gelatine. Th
obtained by boiling fresh bones a lo
mal matter of bones is largely com
tissue.

Scrape ordinary fatty tissue until th
and have the pupils note th at the same
is shown.

7. Structure of the Grains.
water, knife.) Soak a few
night. Cut one open.
darker outer part. The
latter the husk, which is q
Take another grain, and
scrape or peel off the
the layer directly
nitrogenous parts
removed in mak
bread; but the
retained.

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It can be purchased at a drug store, and is used in the place of gum arabic for mucilage.

Boil some starch in vinegar or other acid. When it is soluble in water, it is changed to dextrine. If the boiling be prolonged for several hours, the dextrine will be changed into sugar.

12. **Test for Starch.** (*Materials: Iodine solution, corn-starch, cooked starch paste, teaspoonful of sugar, glasses, water.*) Dissolve 10 grains of iodide of potassium in one ounce of water. Add 5 grains of iodine. Shake well. Stir a teaspoonful of corn-starch into a glass half full of water. Add two or three drops of the iodine solution; stir, and notice the blue color.

Take a spoonful of cooked starch paste, and mix it with the same amount of water. Add the iodine as before, and notice the change in color. Add more water to the glass; still the color remains. Pour off the water and add more, and yet the color remains.

Take another glass, and add a very small amount of the starch paste. To this add a single drop of the iodine solution, and observe carefully the result. In this manner experiment with smaller and smaller amounts, until no change is noticed. Iodine is a delicate and certain test for the presence of starch.

Dissolve a teaspoonful of sugar in a glass half full of water, and add the iodine. There is no reaction. Solutions of other substances may also be tried, and unless starch be present no blue color will appear.

13. **Fats — Emulsions.** (*Materials: White of an egg, butter, water, bottle or tumbler, dish, spoon.*) Place the white of an egg in a dish. Take a piece of butter as large as a chestnut; melt it, and add it to the egg.

Beat the two together thoroughly. Soon it will be seen that the oil and the egg have mixed well. Add half a glass of water, and mix again. (Under ordinary conditions, will melted butter and water mix?) Pour all into a bottle or tumbler, and notice that the oil is evenly mixed throughout the whole mass. This is because the oil, or butter, is broken up into minute globules. The oil is said to be "emulsified." In milk, the oil, or fat, is in this emulsified condition. As the butter in this experiment will soon come to the surface, so will the oil in milk rise as cream. When an oil is digested, it is emulsified; or, to state this in another form, the emulsification of an oil is its digestion.

14. **Sugar—Varieties and Sweetening Power**. (*Materials: Cooking (cane) sugar, grape sugar, sugar of milk, maple sugar.*) Procure samples of ordinary cooking-sugar (cane sugar) and maple sugar. Granules of sugar from dried raisins represent grape sugar. Sugar of milk can be procured at the drug store. Taste each of these sugars.

Make a list, placing the different varieties of sugar in the order of their comparative sweetness.

Make a list of the various staple articles of food that have a sweet taste, indicating opposite each, as far as possible, the form of sugar which gives it that taste.

CHAPTER III.

DIGESTION. — ABSORPTION.[1]

1. **Structure of the Teeth.** (*Materials: Bleached jaw-bone, teeth, hammer, saw, vise.*) [Pupils living in the country can easily procure many varieties of teeth, by keeping a sharp watch for them some weeks ahead of the lesson. The jaw-bones of animals are often found, well bleached after long exposure. In the city specimens of teeth can be procured at the market. When students bring in desirable specimens, ask that these remain the property of the school for future use. In this way some very choice specimens will soon be collected.]

Have pupils examine a tooth, and tell by its shape whether it is for cutting, tearing, or grinding.

As a rule, teeth do not grow after they have fully protruded from the gums. The teeth of the gnawing animals are exceptions to this. They have sharp, chisel-like teeth. Specimens of these are very interesting.

Procure a tooth which has been exposed to the elements a long time; also procure one from an animal recently killed. Notice the crown, neck, and root of the fresh specimen. Look for a small opening in the end of the root for the passage of the nerve and blood-vessels. Break open the dry tooth with a hammer. Notice the shape of the pulp cavity. Study the thickness of the enamel. In an old tooth the enamel can usually be broken away by a few light blows, well directed. Break open the fresh tooth. The pulp is seen to good advantage. Notice its size and color. It is a mass of nerves and blood-vessels. Place a tooth in a vise, and saw it longitudinally and transversely. Study the arrangement of the different parts.

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[1] The Essentials of Health, pp. 57–92; A Healthy Body, pp. 77–93, 101–106; A Primer of Health, pp. 20–29.

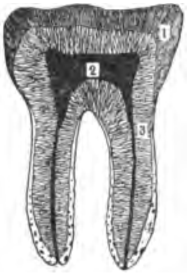

Fig. 2.—Longitudinal section of tooth: (1) enamel; (2) pulp cavity; (3) dentine; (4) cement.

With a hand mirror let each pupil observe his teeth closely, noticing the differences in the shape and size. With a diagram, or with the list as given in the text-books, let each pupil study the arrangement of the teeth until he can locate all in his own mouth and give each its proper name.

Notice the substitute for teeth in fowls. The cutting is done by the sharp edges of the bill; and the grinding is accomplished by the action of fine particles of sand and gravel. The animal swallows the gravel with its food, and these hard bodies are moved about in the crop, grinding the food. The movements of the crop are not unlike those of the human stomach; for in both cases the motion is caused by the contractions of muscles in the walls of the sac.

2. Necessity of Thorough Mastication. (*Materials: Ice, two dishes, warm water, two pine sticks, fire, two lumps of sugar, glass of water.*) To illustrate the necessity of having the food thoroughly masticated, take two pieces of ice of equal size. Crush one into a powder, but do not break the other. Put the same amount of warm water into two dishes. Throw the crushed ice into one dish, and the solid piece into the other. Notice that the finely divided pieces will be dissolved first. Or:

Take two small pine sticks. Have a boy whittle one into shavings. Throw the solid piece and the shavings into the fire together. Notice that the finely divided wood will burn first. Or:

Take two pieces of lump sugar. Crush one into powder. Drop the powder into one glass of water and the lump into another. Stir, and notice which dissolves first.

The conclusion is that the finer the particles, the sooner they will be acted upon. Therefore the finer the solid foods are divided, the larger the surface exposed to the action of the digestive juices, and the more rapid and complete the digestion.

3. **The Stomach.** (*Materials: Portion of pig's stomach, water, magnifying-glass.*) Procure a small portion of the stomach of a pig at the market. Notice the soft mucous lining, and how freely it may be moved over the firm muscular walls. Wash the surface of the mucous covering thoroughly, and examine with a small magnifying-glass; it is possible to see the minute depressions which represent the openings of the gastric glands.

4. **To make Artificial Gastric Juice.** (*Materials: Ten gr. pure pepsin, one half drachm hydrochloric acid, pint bottle, dish of water, thermometer.*) Procure at the drug store ten grains of pure pepsin, also one half drachm of hydrochloric acid. Nearly fill a pint bottle with water,

and add to it the pepsin and acid. Place the bottle in a dish of water, and keep this on the back of the stove. It is quite necessary that a thermometer be kept in the dish of water in order that the temperature may be closely watched and maintained at about that of the human stomach, 102° F. The mixture in the bottle represents the gastric juice ready to digest food.

5. **Action of Gastric Juice on Albumen.** (*Materials: Artificial gastric juice, an egg, water, fine sieve, teaspoon, alcohol lamp.*) Boil an egg for ten minutes. Take the white, as a type of all the albuminous foods. Chop this very fine, or grate it, or pass it through a fine sieve; thus reducing it to fine particles, as is done by thorough mastication. Add a small teaspoonful of the finely divided albumen to the artificial gastric juice. Keep at the proper temperature and shake often, to imitate the movements of the stomach during digestion. After a time the particles of egg will begin to look transparent; they are softening, digesting. After a few hours they will be completely dissolved or digested. To make this experiment a success, it is necessary that the pepsin be good, that the mixture be shaken frequently, and that the temperature be kept at about 102°.

Instead of using finely chopped white of egg, try larger pieces, as large as peas or beans; and notice how much longer time is required for them to become softened or dissolved, — the necessity of thorough mastication is thus clearly indicated.

6. **Both Constituents of Gastric Juice Essential.** (*Materials: Digesting fluid, cooked white of egg, one gr. pepsin, hydrochloric acid, water, three test-tubes, dish.*) Place some of the artificial gastric juice in a test-tube, and

add a small portion of the egg as above prepared. In another tube place one grain of pepsin and three tablespoonfuls of water. Add the same amount of egg as in the other tube. Put a few drops of hydrochloric acid into the same amount of water, and add the same amount of egg as before. Place these three tubes together in a bath of warm water, shake occasionally, and keep the water at the temperature noted above. At the end of three or four hours, look at the tubes carefully, and notice where the digestion or softening has taken place.

7. **Action of Gastric Juice on Milk.** (*Materials: Milk, pepsin, water, pint bottle, hydrochloric acid.*) Place four ounces of fresh milk in a pint bottle. Dissolve ten grains of pure pepsin in a tablespoonful of water. Add the pepsin and water to the milk, and shake the mixture. In a short time the milk curdles; that is, the casein is precipitated. This change takes place at the ordinary temperature, but it is more rapid if the milk be heated to 100° F. before adding the pepsin. In a short time the clot of milk contracts, and a clear liquid, called "whey," is pressed out. This "curdling of milk" is a far different process from the "souring of milk." In the former it is due to a property residing in the pepsin; while in the latter it is the result of a fermentation caused by germs. In each case, however, it is a precipitation of the casein. Because of the absence of hydrochloric acid, the digestion of milk will not proceed further.

To complete the digestion, add to the above a mixture consisting of four ounces of water and fifteen drops of hydrochloric acid. Place the mixture in a water-bath, maintain at a temperature of 102° F., and frequently shake. In two or three hours a considerable part of the casein will be dissolved, and the mixture will have a straw or yellow color, due to the digested casein.

8. **To produce Artificial Pancreatic Juice.** (*Materials: Ten gr. pancreatin and a two-ounce bottle.*) Purchase ten grains of pancreatin. This is a powder prepared from the pancreas of an animal, and represents the active principles of the pancreatic juice. Dissolve the powder in four tablespoonfuls of water, and add thirty grains of bicarbonate of soda (ordinary baking-soda). Use this pancreatic juice to produce —

9. **Artificial Digestion of Fat.** Add to the artificial pancreatic juice prepared as above, a teaspoonful of melted butter. Notice that the butter rises to the surface and remains there. Shake the bottle thoroughly. Keep shaking until the oil and the mixture do not immediately separate. The butter is now broken up into minute globules; it is emulsified. The particles of oil are so small that they are mechanically suspended in the mixture, and do not readily rise to the surface.

After standing, the oil will rise to the surface. By shaking the mixture again, the oil readily mixes with the water. The oil globules remain distinct, as in cream, rather than in the condition of butter.

10. **Action of Pancreatic Juice on Milk.** (*Materials: Milk, pancreatic juice, vinegar.*) Heat four ounces of milk to 100° F., and add two ounces of the artificial pancreatic juice. Maintain the temperature of the mixture at 100° F. In a short time the casein will be precipitated as fine, flocculent particles.

After the mixture has remained in the water-bath for fifteen minutes, remove one half of it to a tumbler. In another tumbler place an equal quantity of fresh milk. Add a teaspoonful of vinegar to each. The milk in the first glass, being strongly alkaline, may effervesce when the acid is added, but this soon subsides. Notice that the clot is much less firm in the milk in the first glass. This is because the casein was already precipitated by the pancreatic juice. Because pancreatic juice precipitates casein in such fine particles, it is often used to "peptonize" milk for invalids and young children. This prevents the formation of hard clots of milk in the stomach.

After the milk has remained in the water-bath for two or three hours the same effect will be noticed as that produced by the gastric juice. The casein, which was first precipitated, will be dissolved, and the mixture will have the characteristic straw-color. It will also have a peculiar odor and bitter taste.

11. **Bile and its Action.** (*Materials: Liver of sheep or pig, with gall bladder, bowl, knife, teaspoon, ounce bottle, melted butter.*) Obtain the liver of a sheep or pig at the market. Procure one with the gall bladder filled with bile. No especial care is needed to insure this, as the gall bladder is nearly always well filled. Wash the liver well, and wipe dry.

Study the color, shape, size, and location of the gall bladder on the under side. Then hold the gall bladder, still attached to the liver, over a bowl or cup. Cut an opening in its walls, and allow the bile to run into the dish.

Place a teaspoonful of the bile in an ounce bottle, and add a teaspoonful of melted butter. Shake the bottle thoroughly. The oil will soon be emulsified, and will remain suspended in the mixture. Bile emulsifies fats, as does the pancreatic juice.

12. **Absorption.** (*Materials: A young plant, bottle, water, cotton or cloth.*) Pull a young plant up carefully by the roots. Shake off the greater part of the soil. Place the roots in an open-mouthed bottle, and add sufficient water to cover them. Make a mark on the outside of the bottle to correspond with the top of the water line. Pack some cotton or pieces of cloth around the plant at the neck of the bottle, so as to prevent the evaporation of the water in the bottle. Notice that after a day or two the water is lowered in the bottle. The minute rootlets have absorbed the water, and it has been carried up by the plant.

A juice called sap may be drawn from trees in the early spring. Let some pupil who has watched the process describe the making of maple sugar from the sap of maple-trees. This sap is composed largely of water, which the minute rootlets of the tree had absorbed from the soil, and which was on its way to the top of the tree to become a part of the new buds, leaves, and limbs.

Compare the action of these roots with that of the minute villi of the intestine.

CHAPTER IV.[1]

THE BLOOD. — CIRCULATION.

1. **To represent Corpuscles of the Blood.** (*Materials: Modelling clay or firm dough, red sugar.*) Procure some modelling clay, or use a firm dough. Roll into balls, the size of marbles. Make one ball slightly larger than the others. Set this one aside, when finished, to represent a white corpuscle.

Press each of the other balls between the thumb and index finger, as illustrated. This will leave the edges round, but the centres concave. These represent the bi-concave red corpuscles. They may be easily colored by rolling in red sugar, if desired. There is

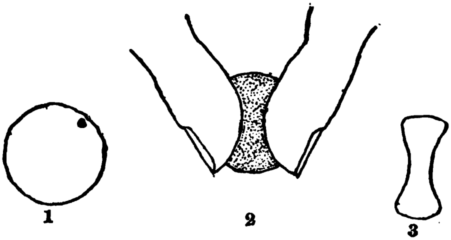

FIG. 3. — Method of illustrating shape of red blood corpuscles: (1) ball of dough; (2) dough pressed between thumb and first finger; (3) fingers removed showing bi-concave appearance of corpuscle.

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[1] The Essentials of Health, pp. 93–118; A Healthy Body, pp. 107–122; A Primer of Health, pp. 35–45.

but one white corpuscle, to illustrate the fact that the red are by far the more numerous.

2. **To examine the Blood.** (*Materials: Drop of blood, cord, needle, paper, piece of glass, glass tumbler.*) Wind a cord around the last joint of the finger, and prick the skin with a needle near the root of the nail. Spread out the drop of blood which exudes, on a piece of glass. Hold the glass over a sheet of white paper, and note the yellow appearance of the drop.

Place another large drop of blood, obtained as above, on a clean piece of glass. Cover it immediately with a small glass tumbler, the interior of which has been moistened, either with water or by breathing on it. Remove the tumbler in five minutes, and note the firm jelly into which the blood drop has set. Remoisten the glass and replace. Examine again in twenty or thirty minutes, when the drop will have separated into two parts, — a little red clot, floating in a nearly colorless fluid, the *serum.*

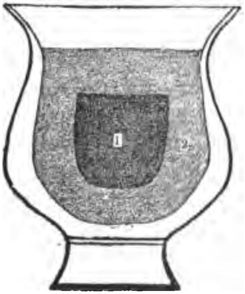

FIG. 4. — Dish of clotted blood: (1) clot, consists of fibrin and blood corpuscles; (2) serum, consists of water, salts, and other ingredients.

Leave a pint fruit-jar or an open-mouthed bottle (as a quinine bottle) at the market. Request that it be filled with blood. Call for it in the morning. Handle carefully, as probably the blood will already be clotted. Notice the clear liquid about the clot; this is the *serum.* The serum contains the albumen, salts, and other important substances. The *clot* contains the corpuscles and the fibrin.

3. **To separate the Fibrin.** Place the jar which contains the blood under a water-tap, and allow the water to run into it for a few hours. In this way it is possible to wash out the corpuscles from the clot, leaving only the fibrin.

4. **How to examine a Heart.** (*Materials: Heart of sheep or calf, scissors.*) Procure the heart of a sheep or calf at the market. The heart of the ox is very desirable for demonstration, only it is so large that it is somewhat difficult to handle. Give directions to have the heart removed in such a way that the enveloping membranes will be uninjured.

(*a*) Notice how the *pericardium* completely covers the heart, as a sac. It even extends over the large vessels at the base.

Cut this sac open with scissors. A few drops of fluid will escape. This is the pericardial fluid.

Enlarge the opening in the pericardium, and cut it entirely away; using care not to injure the large blood-vessels at the base.

(*b*) Study the situation and general appearance of the *auricles*, general shape of the heart, etc. Notice the line which represents the location of the firm muscular wall between the two sides of the heart.

(*c*) *Front of the Heart.* The right *ventricle* forms nearly all the front of the heart when in its normal position in the chest. This ventricle may be distinguished from the left because its walls are much thinner, hence more yielding. There is also a groove, filled with a small amount of fat which separates the two ventricles. This groove is on the front of the heart.

(*d*) *Size of the Ventricles.* Cut the heart transversely at the line (1) indicated in Fig. 5. The wall separating the ventricles now shows clearly. Notice the difference in the shape of the ventricles, as at Fig. 6. The difference in the thickness of the walls of the ventricles is also very apparent.

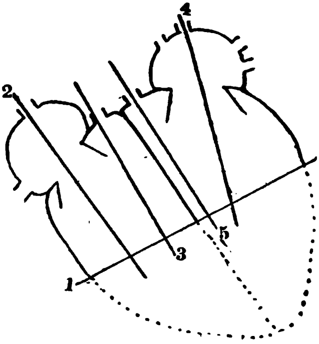

FIG. 5.—Diagram illustrating method of preparing a heart to show circulation through it: (1) Line indicating place for cutting through ventricles; (2) probe passed through vein into right auricle and on into ventricle; (3) probe passed from ventricle into pulmonary artery; (4) probe passed through vein into left auricle and on into ventricle; (5) probe passed from left ventricle into aorta.

5. **Circulation through the Heart.** (*Materials: Heart of sheep or calf, broom splinters, blue thread, red thread.*) Use splinters from an ordinary broom for probes. Pass one probe through a vein into the right auricle, as at Fig. 5. Push it through the auricle into the right ventricle, and leave it in place. Pass another probe from the right ventricle into the pulmonary artery, and leave it also. Tie a blue thread to these, to signify the venous blood.

Pass another probe into a pulmonary vein, through the left auricle and into the left ventricle, and leave it there. Pass another through the left ventricle, into the aorta. Fasten a red thread to these, to signify arterial blood. With these aids point out the circulation of the blood through the heart.

6. **Valves of the Heart.** (*Materials: Heart of sheep or*

calf, blow-pipe or quill.) Remove the probes from the specimen just used. Look into the right ventricle; notice the thin valves which are probably lying back against the walls of the heart, leaving the opening free into the auricle. Notice the same on the other side of the heart.

Cut away the outer half of the auricles (on the line 2, Fig. 7), and study the valves from that side.

Place the heart with the ventricles nearest the operator. With a blow-pipe, or tube of any kind, as a quill or straw, blow a current of air against the valves. The current should be directed between the valves and the walls of the heart, as the valves often lie back against the heart tissue. When the air is back of the valves, the force of the current will throw them out quickly, completely shutting off all communication between the auricle and the ventricle. The observer should look at the specimen from the side opposite that of the experimenter, that is, from the auricle side.

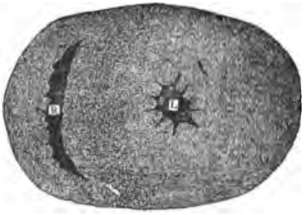

FIG. 6. — Appearance of severed heart when cut at line (1), Fig. 5.

By the exercise of ingenuity on the part of the operator, it will be possible to illustrate the action of all the valves of the heart in this manner.

7. **The Pulse.** Place the inner surface of the end of the second finger over the wrist on the radial, or thumbside. Notice Fig. 8 to learn the location of the radial artery. Let the pupil count his own pulse, then that of a friend. Count at least half a minute; better still, a full minute.

The pulse is easily felt at the side of the neck. Also notice that when sitting with one leg crossed over the knee of the other, the end of the foot is often seen to move slightly with each beat of the heart.

Count the pulse when sitting, when standing; then swing the arms vigorously, and count again. The pulse should beat faster after each of these changes, — faster when standing than when sitting, because more muscles are being exercised; and faster after swinging the arms or running, for the same reason.

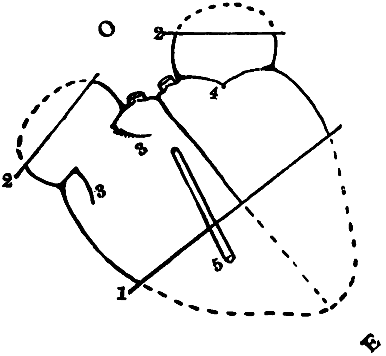

FIG. 7. — Diagram illustrating method of preparing a heart to show action of valves: (E) position of experimenter; (O) position of observer; (1) line indicating place for cutting through ventricles; (2) lines indicating places for cutting through auricles; (3) valves open; (4) valves closed; (5) tube for forcing air against valves to close them: notice that tube is directed between the wall of the heart and the valve.

8. **Study of Arteries and Veins.** (*Materials: Specimen of heart with aorta attached.*) The best illustration of an artery is the aorta. Remove it from the last specimen. It is recognized as the large vessel, with firm, thick walls, of a light yellow color, empty, and always retaining its circular form. In a specimen with the aorta attached to the heart, it is interesting to lift the heart by grasping the aorta. The great elasticity of this vessel is clearly demonstrated in this way.

Study the veins in the same specimen. In these vessels the walls are thinner, less elastic, and when cut transversely they collapse and appear flat, presenting in this respect a marked contrast to the arteries.

Draw a bandage closely around the forearm, just below the elbow, and let the arm hang down by the side. The veins will fill out with blood. Move the hand from the wrist up along the forearm, over the most prominent veins. Then move the hand from the elbow down the forearm to the wrist, trying to push the blood in that direction. Often a vein on the back of the hand will clearly show this action of the valves in checking the backward flow of the blood.

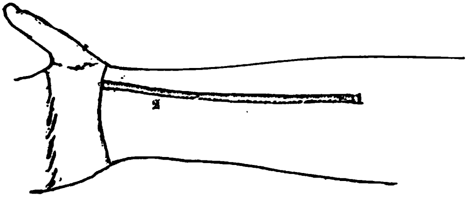

Fig. 8. — Diagram illustrating position of radial artery (pulse), inner side right arm: (1) artery; (2) point at which pulse is best felt.

CHAPTER V.

THE LUNGS.[1]

1. **Preparing Specimen for Demonstration.** (*Materials: Lungs of rabbit or sheep.*) The lungs of an animal the size of a rabbit are best adapted to demonstration. The lungs of a sheep are more difficult to inflate, but the demonstration is more striking. In any case they should be procured from an animal recently killed. When removing the lungs, use great care not to injure the lung-tissue in any way. A slight puncture with a knife may completely defeat an experiment.

If special directions are given at the market, the upper air-passages of a sheep may be procured, which will show the epiglottis, and the larynx with its vocal cords.

Wash the lungs well in water, and wipe dry. Remove any masses of loose connective tissue, fat, or muscle, in order that the specimen may present as neat an appearance as possible.

2. **Upper Air-Passages.** Cut open the larynx to study the transverse bands of tissue called the vocal cords. These are often seen lying close to the sides of the larynx, and are not detected at first glance.

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[1] The Essentials of Health, pp. 124–150; A Healthy Body, pp. 127–139; A Primer of Health, pp. 50–61.

The trachea is easily recognized by its rings. Notice that the hard part of the rings is not complete on the back, for a band of tissue completes the circle. A careful examination will show that the trachea divides, low down, into two branches, one for each lung.

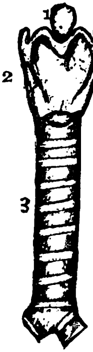

FIG. 9. — Upper air passages: (1) epiglottis, not seen so prominent in actual specimen; (2) larynx; (3) trachea, dividing below into two branches.

3. **Inflating the Lungs.** (*Materials: Specimen prepared as above, glass tube, bellows.*) Insert a tube in the trachea. A small glass tube answers for the lungs of an animal the size of a squirrel; but for a sheep a much larger tube is necessary. An ordinary pair of bellows is very convenient for use in inflating lungs as large as those of a sheep. The best tube is a regular blow-pipe with a stop-cock, or key, which can be turned to prevent the air from escaping after the lungs are once inflated.

Tie the tube in place and breathe into it, thus forcing air into the lungs and causing them to expand fully. The mouth can be slipped from the tube, and the thumb quickly passed over the end of the tube, without allowing much air to escape. On removing the thumb, it is seen that the lungs quickly contract to their former size.

4. **Mechanism of Respiration.** (*Materials: Open-mouthed bell-jar with cork; glass tube or quill; sheet-rubber; lungs of guinea-pig or rabbit; or a rubber bag or toy-balloon.*) To illustrate the mechanism of respiration, a simple piece of apparatus may be constructed as follows: —

Procure an open-mouthed bell-jar;[2] have a cork fitted tightly to it. Through the centre of the cork pass a glass tube, or one made from a quill; cover the bottom of the jar with sheet-rubber, such as is used by dentists. Have all the parts as nearly air-tight as possible.

Procure the lungs of an animal the size of a guinea-pig or rabbit. Remove the cork from the jar, and tie the trachea around the lower end of the tube. Press on the under side of the rubber covering, thus pushing it up well into the jar, as shown by the dotted line in Fig. 10. With the rubber diaphragm well pushed up and held there, put the lungs into the jar and push the cork in tightly.

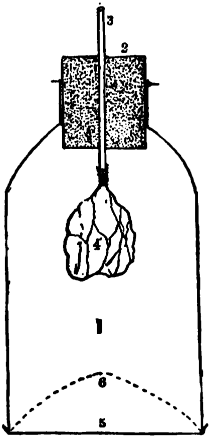

FIG. 10. — Apparatus to illustrate thorax, with expansion and contraction of lungs: (1) open-mouthed bell-jar; (2) cork, pierced in the centre for passage of tube (3); (4) lungs of small animal, or a rubber bag; (5) rubber sheet fastened over end of bell-jar; (6) rubber pushed into jar, representing the diaphragm in expiration.

The jar now represents the thorax, with only one opening in it, — the tube or trachea. The rubber represents the diaphragm, very concave on the under side, as in expiration. The hand is still holding the rubber pushed up into the jar. Now remove the hand from the rubber. The rubber contracts; the space in the jar is made larger, air rushes in through the tube; and the lungs expand. Press again on the rubber diaphragm and the lungs will collapse, as in expiration.

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[2] If such a jar is not to be had, a substitute can be made from any open-mouthed bottle of proper size, by removing the bottom of the bottle.

Remove the hand again and the lungs will expand, as in inspiration. When this apparatus is well made, it is very effective and amply repays for all the trouble.

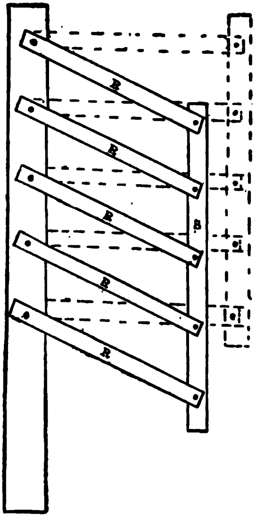

FIG. 11. — Apparatus to illustrate that when the ribs (R) are raised, the sternum (S) is raised and pushed forward, thus increasing the antero-posterior diameter of the chest.

When the lungs of an animal cannot be procured for this demonstration, a rubber bag, such as a toy-balloon, answers very well.

5. **To Measure the Expansion of the Chest.** (*Materials: Tape, pieces of wood, screws.*) That the chest expands during inspiration is easily shown by passing a tape around the upper part of the thorax, beneath the arms. Exhale all that is possible, keep the tape tightly drawn, and note the size. Then inhale slowly and as fully as possible. Allow the tape to slip through the fingers as the chest enlarges. When fully expanded, note the size again and see how many inches the chest-measure has increased.

The function of the ribs and sternum in the act of respiration can be illustrated by a little apparatus made from a few pieces of wood and a few screws, as pic-

This can be easily done by a number of simple processes, such as soaking a cord in alcohol, pulling it tightly around the bottle, and setting fire to the string. As soon as it is consumed, plunge the bottle into cold water, and then tap the bottom with a hammer. Take care to file off sharp edges.

tured in Fig. 11. This clearly shows that when the ribs and sternum are raised, as in inspiration, the distance between the sternum and spine will be increased, and the thorax made larger, thus demanding more outside air to fill the larger space.

6. **Respirations per Minute.** Count the number of respirations per minute. Notice that this number is not far from one-fourth the number of pulsations of the heart.

7. **Carbonic Acid in Expired Air.** (*Materials: Glass of lime-water, glass tubes or straws, open-mouthed bottle, cork, rubber tubing.*) Procure a glass of ordinary lime-water at the drug store. Immerse the end of a glass tube or straw in the water. Place the mouth at the free end of the tube, and force the expired air through the water by blowing into the tube. The water will soon appear milky. This is because the carbonic acid in the expired air has united with the small amount of lime in the water, making the carbonate of lime.

Fit a cork into an open-mouthed bottle; perforate the cork with two holes. Through one hole pass a glass tube long enough to reach nearly to the bottom of the bottle. Through the other hole pass another tube, just long enough to protrude through the lower edge of the cork. On the outer end of the second tube place a foot of rubber tubing. Fill the bottle half full of lime-water, and fit the cork in position. Suck air through the rubber tubing. This will draw the air of the room through the lime-water; and if this air is reasonably pure, the amount of carbonate of lime precipitate will be slight as compared with the amount of precipitate in the preceding experiment. In this way it is conclusively shown that the air expired contains much more carbonic acid than the air inspired.

8. **Water in Expired Air.** Breathe on any highly polished surface, such as a mirror. The vapor is condensed and appears as water.

9. **Expired Air is Warmer.** In winter we recognize that the expired air is warmer than the surrounding air when we blow upon the fingers to warm them. Breathe on a thermometer which has been exposed to the air of the room. Note how quickly the mercury rises, showing the expired air to be warmer than it was when taken into the lungs. In the hottest weather in summer it is possible for the surrounding air to be warmer than the expired air.

10. **Necessity of Ventilation.** (*Materials: Jar, sheet-rubber, tube, candle, metal base or cardboard, glass plate, thin piece of wood.*) Remove the rubber from the jar shown in Fig. 10, and close the tube. Set a short piece of lighted candle on a metal base, or on a thick piece of cardboard. Place the jar over the candle. Notice that the flame is soon extinguished. The candle ceases to burn when the oxygen in the jar is exhausted.

Wet a glass plate or a window glass; set the short lighted candle upon it; put the jar over the candle with the tube in the cork open. (The piece of glass is made wet, that the jar and glass may fit air-tight, which is necessary to the success of the experiment.) Notice that, although there is an opening at the top of the jar, the candle burns dimmer and dimmer, and at last goes out.

Remove the jar. Light the candle again, and replace the jar with the tube open. When the candle begins to burn dimly, as it did in the last experiment, place a thin piece of wood beneath the lower edge of the jar. Notice how quickly the flame starts up again. Good ventilation requires that provision be made both for the free admission of an abundance of pure air and for the carrying off of the impure air.

CHAPTER VI.

THE BONES.—THE SKELETON.[1]

FOR some time previous to this lesson be on the alert for any pieces of bone. It is difficult to find a bone of any kind which will not prove useful. Boys in the country have an unusually good opportunity to make an interesting collection of a variety of bones.

1. **Surface Examination.** (*Materials: Bones, knife.*)

(*a*) **Grooves and Prominences.** Notice the rough eminences, especially at the ends of the long bones, for the attachment of muscles and ligaments. Also look for smooth grooves for the passage of blood-vessels. Sometimes it is possible to trace one of these grooves until it terminates in an opening which passes into the bone.

(*b*) **Openings for Blood-Vessels.** It is interesting to notice the minute openings over the surface, for the passage of the smaller blood-vessels into the bone, to supply it with nourishment. These openings are scarcely large enough for the end of a pin to enter, and they are quite thickly distributed.

(*c*) **Periosteum.** Procure a piece of fresh bone at the market. Remove any attached muscle or tendon. With the point of a knife, cut down on the bone and peel off the thin membrane. This membrane is the periosteum. Notice how tightly it clings to the bone.

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[1] The Essentials of Health, pp. 156–177; A Healthy Body, pp. 26–44; A Primer of Health, pp. 110–125.

2. **Gross Structure.** (*Materials: Bleached bone, saw, vise.*) If possible, procure a bone which has been exposed to the elements and is well bleached. Fasten it carefully in a vise, and saw it longitudinally. One of the long bones is best for this purpose. The section should be made through the ends as well as through the shaft. Have a number of these sections sawed from different bones. Such sections show the spongy portion of bone in a very beautiful manner.

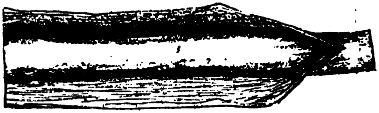

FIG. 12. — The periosteum, peeled from a fresh bone.

Make a transverse section through the shaft and through the end of a long bone, as illustrated in Fig. 13.

3. **Marrow.** Saw a fresh bone transversely to obtain the marrow. The fat in the marrow gives to fresh bone its oily or greasy appearance and feeling.

4. **Mineral Matter.** (*Materials: Burned bone, fresh bone, hammer.*) Previous to the lesson, burn some pieces of bone by placing them in the fire for a few hours. They should be burned until white, and then carefully removed from the fire.

Take these into the class with pieces of fresh bone. Strike the fresh bone with a hammer; it does not break. Strike the burned bone; it breaks easily, provided it is well burned. The heat has consumed the connective tissue, the animal matter; leaving nothing but the mineral matter. Hence it is nearly as brittle as chalk.

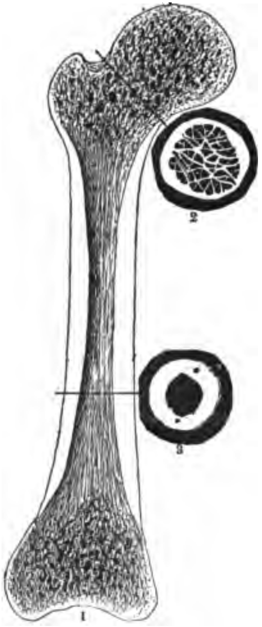

FIG. 13. — Sections of bone: (1) longitudinal section of a long bone; (2) transverse section through the neck of said bone at point indicated by heavy line, showing the spongy bone within; (3) transverse section of the shaft of said bone at point indicated by heavy line, showing centre of bone hollow (filled with marrow) and two large blood-vessels in bony walls.

5. **Animal Matter.** (*Materials: Leg of young fowl or rib of young sheep, water, nitric acid.*) Take the leg of a young fowl or the rib of a young sheep. These should be fresh. Cut away all fat, muscle, and connective tissue. Place the bone in a mixture of nitric acid one part, and water four parts. This is a strong solution; weaker ones could be used, but in that case the time of the immersion of the bone must be prolonged. The bones should remain in the solution until a needle will easily penetrate them, showing that the mineral matter has all been dissolved. Then pour off the acid solution, and wash the bones thoroughly in water. Let them soak in water for a few hours before handling them, so that all the acid may be removed. It is difficult to estimate how long a time will be required for the acid to dissolve the mineral matter, as so much depends upon the size of the bone. A small bone, like

the rib of a common fowl, can be softened in a few hours, while the leg-bone of a fowl will require from six to twelve hours, when the stronger solution is used.

Notice how soft the bones are, and how easily they can be bent. If the bone is long enough, and if the mineral matter is all dissolved, it is possible to tie it in a knot. This experiment of tying a bone is very striking, especially when such a large bone as the rib of a sheep is used.

6. **The Skull.** (*Materials: Skull of a small animal.*) Ask the pupils to try to procure the skull of some small animal, one not larger than that of a rabbit. The bones must be well bleached and very clean. Retain the best specimens for future use.

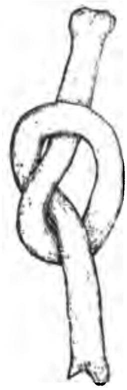

FIG. 14. — Rib of small animal from which all mineral matter was removed and then easily tied in a knot.

Notice how well protected the cavity of the brain is; also the bony protection afforded the eye. Look for the small opening in each side for the organ of hearing. Examine the large opening at the base, or under side of the skull, for the entrance of the spinal cord and large blood-vessels. Notice the insertion of the teeth.

Look for two rounded prominences, one on either side of the large opening in the base of the skull. These rest in corresponding depressions in the first vertebra, forming joints upon which the head moves forward and backward.

7. **Atlas and Axis.** (*Materials: First two vertebræ of sheep.*) One of the most interesting illustrations of the

wonderful mechanism of the body is furnished by the atlas and axis. These bones are occasionally found about the fields, and with some care an interesting collection can soon be obtained for use with future classes.

The first two vertebræ of a sheep can easily be procured at the market, and after boiling, all the tissues can be readily removed. The bones are thus made to show to good advantage. In fact, this method of boiling fresh specimens obtained at the market can be taken advantage of in a great many instances. Prolonged boiling will so soften the tissues that they may be quickly removed, leaving the bones in a clean uninjured condition. If the boiling be not too long, it is possible to remove the muscles and leave the ligaments, as the latter are not so easily softened.

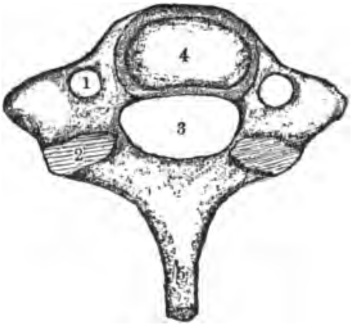

Fig. 15. — A typical vertebra: (1) opening for blood-vessels; (2) points of articulation with vertebræ; (3) central opening for spinal cord; (4) place of attachment of elastic cartilage; (5) spine extending posteriorly, or toward the surface of the back.

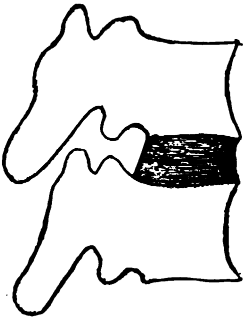

Fig. 16. — Two vertebræ, showing position of elastic cartilage between them.

8. **The Vertebræ.** (*Materials : Vertebræ of ox.*) Take

a portion of the spinal column of any animal, as a few vertebræ of the ox. Boil these for a few hours, and remove all the soft tissues.

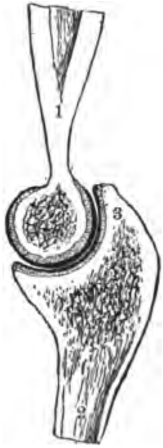

Fig. 17.—A hinge joint (the elbow), cut longitudinally: (1) the arm bone; (2) bone of forearm; (3) projection of bone which forms the point of the elbow when the arm is flexed.

Notice the central opening for the protection of the spinal cord; the smaller openings at the side for the passage of blood-vessels; and the spines, or sharp prominences, for the attachment of muscles and ligaments.

Procure at the market three or four inches of the spinal column of an ox or sheep. Have the vertebræ cut longitudinally, as they may often be seen as the meat hangs in the market. Notice the cushions of white elastic cartilage between the vertebræ. This cartilage is hard, does not cut easily, and yet is very elastic. Illustrate this elasticity by moving the vertebræ.

9. **The Joints and Attachments.** (*Materials: Foreleg of sheep, ball-and-socket joint, knife.*)

(*a*) To illustrate the joints, procure specimens at the market. For a hinge-joint, obtain the foreleg of a sheep. Have it cut off about two inches above, and the same distance below, the knee. Similar joints can easily be procured. Have one specimen preserved entire, and another cut longitudinally. The parts will then show to very good advantage.

Obtain two ball-and-socket joints, — one entire, and the other opened. An intelligent man at the market will understand how to prepare some other useful specimens.

(*b*) **Ligaments.** Take one of the entire joints, and dissect away all fat and muscle, leaving only the firm and strong ligaments. By calling attention to the strength and firmness of these ligaments, it will be

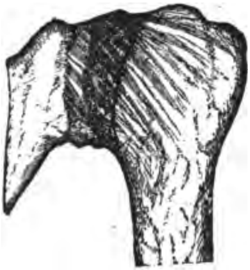

FIG. 18. — A ball and socket joint (the shoulder), completely covered with ligaments.

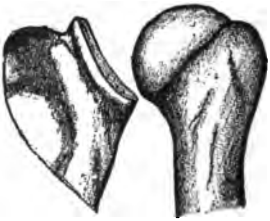

FIG. 19. — Same joint as Fig. 18, with all ligaments removed.

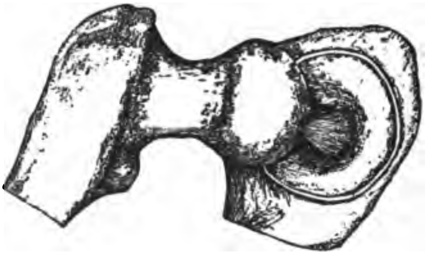

FIG. 20. — Ball and socket joint (the hip), with all ligaments removed except the one which extends from the centre of the ball to the centre of the socket.

better understood how the bones are so securely held together at the joints.

(*c*) **Synovial Fluid.** Pierce a joint with the point of a knife, and a thin fluid will exude. This is the synovial fluid, or joint water.

Enlarge the opening, and notice the smooth, glistening lining of the ligaments. The smooth covering of the cartilage at the ends of the bones also shows to advantage. Cut this cartilage away until the bone is reached, thus showing the thickness of the former.

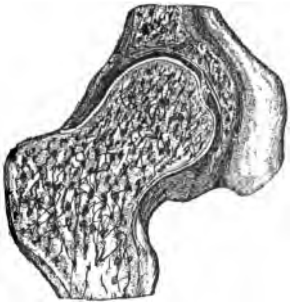

FIG. 21. — Ball and socket joint cut longitudinally, showing bones in proper place and ligaments surrounding joint.

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CHAPTER VII.

MUSCLE. — SKIN.[1]

1. **Muscle Fibres.** (*Materials: Piece of corned beef, two needles.*) To show that muscle is composed of fibres, boil a piece of corned beef. This meat is preferable, simply because the salt water, or brine, has hardened the fibres, while long boiling softens the connective tissue which holds the fibres together.

Take a shred of this meat one-fourth of an inch in length, and of the diameter of an ordinary pin. Place a drop of water on it to keep it moist, and with the points of two needles pick the fibres apart until some of them appear as minute threads. Even the smallest of these threads of tissue is composed of still smaller fibres.

2. **Muscle and Tendon.** (*Materials: Foreleg of sheep, leg of a fowl, knife.*) Get at the market the foreleg of a sheep. Have it cut off three or four inches above the knee. Cut away the skin, fat, and loose connective tissue. Below the joint separate the tendons from each other by the careful use of the knife. Above the joint, separate the muscles, and dissect them from each other down to their termination in the tendons, just before

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[1] The Essentials of Health, pp. 180–188, 202–214; A Healthy Body, 47–52, 145–152; A Primer of Health, 86–91, 103–109.

they pass over the joint. Pull on the muscles, and note the effects on the parts below.

Obtain almost any joint, and dissect the tendons around it. Notice the deep grooves in which they are sometimes found. One of the best specimens for demonstration is the leg of a common fowl. Remove the leg at the second joint. Cut away all the skin covering the fleshy part, and carefully separate the muscles from each other. Notice how the muscles grow smaller, and terminate in tendons, as they approach the joint.

Pull one of the muscles at the front of the leg, and notice the effect on the foot and toes. Try one of the deeper muscles. Try the muscles on the back of the leg also.

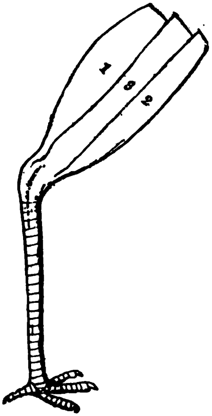

FIG. 22. — Leg of a common fowl: (1) muscle on the posterior surface of leg; (2) muscle on anterior surface, deeper muscles not shown; (3) bone.

3. **The Skin.** (*Materials: Magnifying-glass, stem of plant.*) Let each pupil examine the skin of his hand, with the aid of a magnifying-glass, and record as many facts as he can learn through such observation. Let each one examine the stem of a plant, and note the tiny hairs, and the covering that corresponds to the epidermis.

4. **Sweat-Glands.** (*Materials: Magnifying-glass.*) With an ordinary magnifying-glass examine the inner surface of the end of one of the fingers. If the glass is of sufficient magnifying power, minute depressions may be seen, as illustrated in Fig. 23. It is often possible to

see tiny drops of moisture resting directly over these depressions. These are drops of perspiration escaping from the sudoriferous, or sweat-glands.

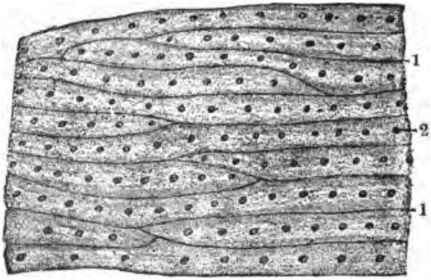

FIG. 23. — Inner surface of index finger, when viewed with a strong pocket magnifying-glass: (1) lines seen with unaided eye; (2) minute depressions seen with magnifying-glass.

5. **The Nails.** The frequent necessity of trimming the nails may be used as an illustration of the rapidity with which the cells of the various tissues reproduce themselves. A minute shaving from the nail consists of vast numbers of cells; yet the cells multiply so fast at the base of the nail that in a few days the nail is as long as before the clipping.

CHAPTER VIII.

THE NERVOUS SYSTEM.

1. **The Exterior of the Brain.** (*Materials: Brain of a sheep, blunt-pointed probe or pen-holder.*) Order the brain of a sheep at the market the day before the study of this lesson, and leave a plate on which it may be placed. Direct that the skull be sawed very carefully, sawing through the bone, and no farther; otherwise the brain will be badly torn. Ask that great caution be exercised in taking the brain from the skull, and have all the connections on the under side cut off with care. Much of the value of the succeeding demonstrations will depend upon success in procuring the brain in as perfect a condition as possible.

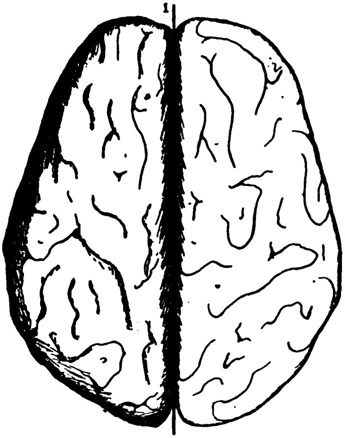

FIG. 24. — Brain viewed from above, showing the line (1) separating the two hemispheres.

(*a*) **Division of the Cerebrum.** Notice the division of the cerebrum into two parts by a median fissure. By gently pushing aside each part, it can be seen that this fissure is not a complete one. There is a band of connecting tissue within.

(*b*) **Membranes.** It is possible that all three membranes which cover the brain may still be intact in the specimen procured. But the outer, hard membrane clings closely to the skull, and unless special care be used it is likely to be torn away with the removal of the

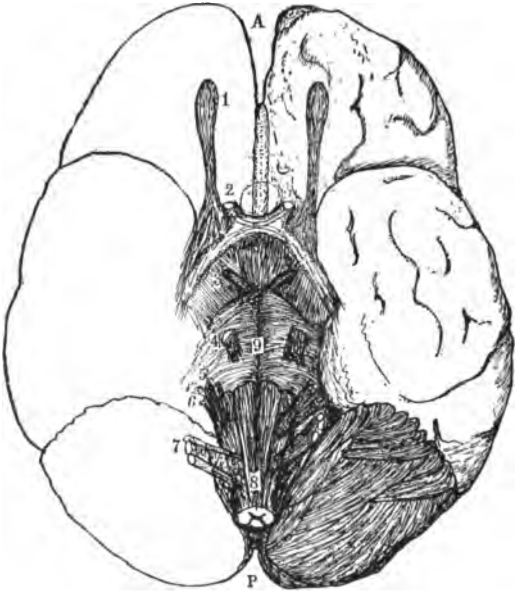

FIG. 25. — Under surface of brain: (A) anterior; (P) posterior; (1) olfactory nerves; (2) optic nerves; (3) motor nerves of eyeball; (4) nerve of common sensations; (5) motor nerve of face; (6) acoustic nerve; (7) pneumogastric nerve; (8) medulla, the severed end of which has the characteristic appearance of the spinal cord; (9) the pons.

brain from its bony cavity. The middle membrane is extremely thin, and difficult to demonstrate. After the two outer membranes have been removed, the delicate inner membrane can be raised from the surface of the brain by the aid of fine forceps. It contains the vessels which supply the brain with blood, and dips down into the cavities between the convolutions.

(*c*) **Convolutions.** Study the convolutions, their number, shape, etc. Pass a blunt-pointed probe, as the small end of a pen-holder, down between the convolutions, to show their depth.

2. **The Interior of the Brain.**

Gray and White Matter. (*Materials: Prepared specimen of brain, long-bladed knife.*) With a long-bladed knife remove a portion of the upper part of the cerebrum, as at the line (1), Fig. 25. Notice the two colors of the tissue, — a pale gray and a white. The gray matter, consisting largely of cells, is seen on the outside. It composes nearly all the convolutions. The white matter, consisting largely of fibres, is within, forming the centre of the convolutions.

The Cerebellum. Notice the absence of convolutions on the cerebellum, the smaller brain, beneath and at the back of the cerebrum, and the series of transverse folds or pleats in their place.

The Medulla. Note beneath the cerebellum the medulla, which appears as an enlargement of the cord below.

Under Surface of the Brain. Turn the brain over to examine its under surface. Notice the band which unites the two parts of the cerebrum.

3. **The Origin of the Cranial Nerves.** The olfactory

nerves, or olfactory lobes, proceed from the under surface of the anterior portion of the cerebrum.

The optic nerves, the nerves of sight, can be seen, cut close, at the anterior edge of the cerebrum. They pass back, forming the optic tracts, which can be easily discovered by the peculiar crossing of the fibres.

Immediately back of this is a pair of nerves which supply nearly all the muscles of the eyeball, including the iris.

Back of these is a pair of nerves the largest of all. Each is the great sensitive nerve of the head and face. It controls nearly all the muscles of mastication; and some of the fibres go to the tongue for the special sense of taste.

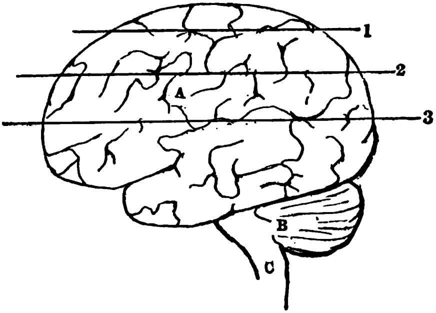

FIG. 26.—Diagram of brain, showing lines for dissection: (A) cerebrum; (B) cerebellum; (C) medulla.

Directly back of the above is the pair of nerves which control the action of the muscles of the face.

Back of the above is the pair of nerves for the sense of hearing.

Back of the above, at the side of the medulla, is the great pneumogastric nerve. This nerve supplies the organs of the voice and respiration with sensory and motor fibres. It also sends motor fibres to the œsophagus, stomach, and heart.

In man there are twelve of these cranial nerves.

4. **Interior of the Brain.** (*Materials: Brain of a sheep, large knife.*) Turn the brain again to its normal position. Make another section with the large knife at the line (2), Fig. 26. This will be about on a level with the top of the connecting band of tissue. Notice that this band neither extends fully to the front nor to the back, and yet connects the two cerebral hemispheres.

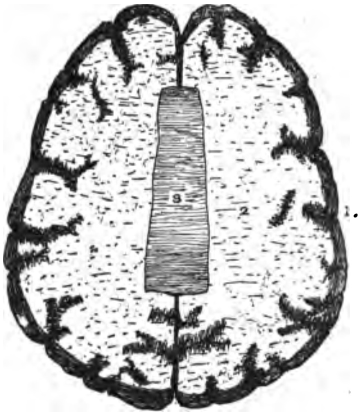

FIG. 27.—Surface of the brain exposed after removal of portion above line 2, Fig. 26: (1) the outer, gray substance (heavily shaded); (2) the inner, white substance; (3) tissue which connects the two hemispheres.

Cut away another section half an inch lower than the last, on the line (3), Fig. 25. This exposes a complicated structure, which only complete works on anatomy fully describe. Two cavities are seen, one on either side. These are the lateral ventricles. They are lined with a delicate membrane, and moistened by serous fluid.

5. **The Spinal Cord.** Notice, as a beef hangs in the market, that it is usually cut down the spinal column,

each side hanging separately. In cutting down the vertebræ, however, the saw or axe rarely goes down the exact median line. Thus the spinal canal is laid open, and the cord exposed. By taking a sharp-pointed knife and cutting out the uninjured portions, it is often possible to obtain two or three inches of the cord in good condition.

(*a*) **Membranes of Cord.** Notice that the cord is surrounded by membranes similar to those which cover the brain. The outer thick membrane shows here to good advantage.

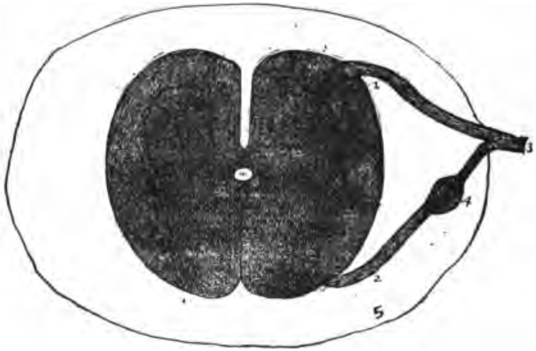

FIG. 28. — Transverse section of spinal cord with surrounding membranes: (1) anterior, motory root to spinal nerve (3); (2) posterior, sensory root; (4) gland of posterior root; (5) the dura mater, other enveloping membranes not shown.

(*b*) **Spinal Nerves.** Fibres can be seen coming from the sides of the cord, passing through the membranes, and showing on the outside. These are the spinal nerves.

(*c*) **Roots of Nerves.** Carefully cut away the membranes, clipping off the fibres of the inner side as close to the membrane as possible. Notice the two roots of each nerve (1), (2), Fig. 28. Careful inspection will show a slight enlargement (4) on the posterior root.

(*d*) **Transverse Section of Cord.** With a sharp knife cut the cord transversely. Look closely for the central canal. The fissure down the anterior surface is clearly seen in some parts of the cord, but not so well shown in others. The posterior fissure is less clearly seen, or, more usually, cannot be seen.

(*e*) **Gray and White Matter.** Notice the difference between the shading of the inner and outer portions of the cord. The gray matter is within, and the white without, just the reverse of the arrangement in the brain. Notice that the inner, darker gray matter is arranged somewhat after the shape of the capital letter H.

6. **Knee-Jerk.** Have a pupil sit on a chair before the glass, and cross one leg over the other. With the tips of his fingers have him strike the upper leg just below the knee-pan. The foot will be thrown forward with a jerk. Notice that there is a short period of time between the striking of the tendon below the knee-pan and the jerk. This time is occupied by the nerve current passing up the sensory nerves to the spinal cord, and back again through motory nerves to the muscle on the front of the thigh. The act is purely reflex, the brain not being actively engaged.

Ask the pupil to throw the foot forward as it was moved before. Call attention to the fact that the first act was involuntary, and the last voluntary.

These two experiments can be illustrated on the board with diagrams. The first is illustrated as follows: Reproduce Fig. 28 on the board, and trace the nerve current from the knee up the nerve (3), along the sensory root (2), out the motory root (1), and down to the muscle of the thigh. Reproduce Fig. 89 of The Essentials of Health, and note that this reflex act did not involve the central nervous system higher than that part of the cord from which the nerves arise that supply the lower limbs, namely, the lower third.

To illustrate the second experiment it is necessary to explain that the stimulus or exciting cause of the nerve current originated in the brain. The nerve current passed down the spinal cord until it reached the same portion of the cord that was involved in the first experiment. The current then passed out of the cord through the anterior motory root, and down to the muscle on the front of the thigh. In the first experiment the stimulus was the striking of the fingers, and the brain was not involved. In the second, the stimulus originated within the brain, which was, therefore, involved.

7. **Other Reflex Acts.** Illustrate the fact that the brain is not necessary for the performance of a reflex act by recalling that in sleep if the foot be tickled the limb will be withdrawn. In this case the nerve current of sensation entered the cord through the posterior, or sensory root, and immediately passed out again through the anterior, or motory root, without going to the brain. Positive proof of this rests on the fact that the same act will be performed when an animal has no brain.

Call attention to the large number of reflex acts constantly going on in the body, as the flow of saliva when food is introduced into the mouth, and the flow of gastric juice when food reaches the stomach. Also call attention to acquired reflex acts, as walking, playing the piano, and skating.

CHAPTER IX.

THE EYE.[1]

1. **Preparation of Specimens.** Procure the fresh eye of an ox at the market. Give directions that the eyeball be cut from its socket by passing the knife as close to the bony walls as possible, thus preventing injury to the eye itself. Remove all the fat with forceps and scissors or knife. Provide also, for the succeeding experiments, some pins, thread, and water.

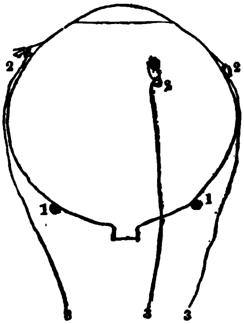

FIG. 29. — Diagram to illustrate how action of muscles of eyeball may be shown: (1) pins introduced into board against which eyeball rests; (2) severed ends of muscles to which strings (3) are attached.

2. **Muscles of Eye.** Probably the muscles have been cut quite closely to the eyeball; but a small portion of each muscle will remain, as at (2), Fig. 29, showing the points of attachment. Tie threads (3) around these short ends. Place two pins in a board to hold the eye in position. By pulling on any of these threads, the eyeball will be moved, thus

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[1] The Essentials of Health, pp. 296–305; A Healthy Body, pp. 180–186; A Primer of Health, pp. 132–137.

giving an idea of the action of the particular muscle to which the thread is attached.

3. **Optic Nerve.** The optic nerve is seen at the back of the eyeball, resembling a white cord, about one-eighth of an inch in diameter. Notice that the nerve does not enter the eyeball at a point directly opposite the front of the eye, but, as will also be seen from Fig. 30, just below this.

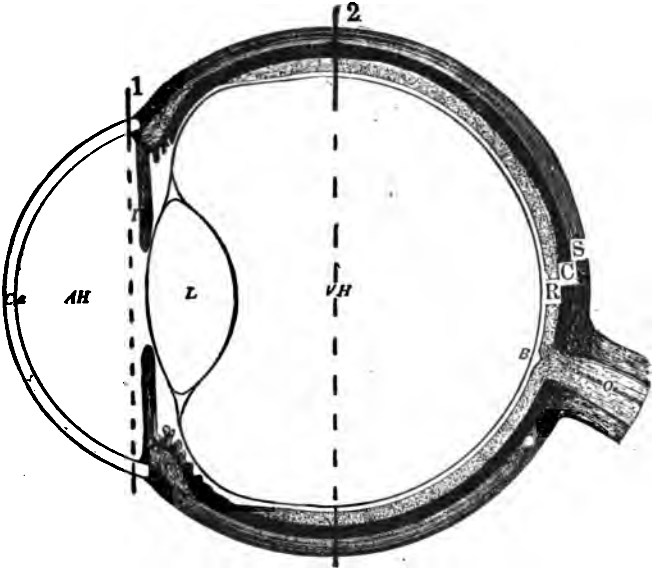

Fig. 30. — Section of eyeball, antero-posterior: (1) line of incision for removal of the cornea; (2) line of incision through centre of eye transversely; Ca, the cornea, or the transparent membrane which forms the front of the eye; S, the sclerotic; C, the choroid; R, the retina; O, the optic nerve; B, the blind spot; I, iris; L, the lens; AH, the aqueous humor; VH, the vitreous humor.

4. **Cornea. — Sclerotic.** Look directly at the front of the eye. The outer membrane is transparent; this is the cornea.

Back of this is the hard membrane which covers the posterior two-thirds of the eyeball; this is the sclerotic. The cornea and the sclerotic form the outer covering of the eyeball.

5. **Iris. — Pupil.** Look through the transparent cornea, at the colored membrane beyond: this is the iris. It is pierced in the centre with a circular opening, the pupil. In the iris are two sets of muscle-fibres. The contraction of one set of muscle fibres causes the pupil to become smaller; the contraction of the other set has an opposite effect.

6. **Aqueous Humor. — Lens.** Pass the sharp-pointed blade of the scissors or of a knife through the cornea where it joins the sclerotic. Cut round the eye on this line, completely removing the cornea. A watery fluid escapes; this is the aqueous humor. The iris now shows well, with its central opening, the pupil. Directly back of the pupil is the lens.

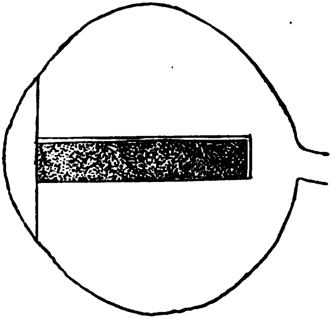

Fig. 31. — Diagram to illustrate how a section of the sclerotic can be removed in order to show the choroid beneath.

7. **The Choroid.** With sharp and fine scissors, begin at the border of the cornea and cut through the sclerotic. Cut toward and to the optic nerve. Use great care not to cut too deep,

— only through the membrane. Cut another line, parallel to this, and distant from it about one-fourth to one-half an inch. With delicate forceps carefully lift up this strip and cut it away. Beneath it should be the dark-colored choroid.

8. **The Retina.** Near the optic nerve pick off the choroid with the forceps; that is, remove the dark layer. A light-brown membrane lies beneath; this is the retina.

9. **Vitreous Humor.** With the scissors cut through the eye at the line (2), Fig. 30. Carry the incision completely around the eye, thus dividing the eyeball into two parts. Notice the semi-glutinous fluid which filled all the posterior part of the eyeball; this is the vitreous humor. Place the parts in water; gently move them about, until this humor is well washed away.

10. **Blind Spot of the Eye.** Examine the posterior portion after washing as stated above. Notice the point on the inner side, opposite the entrance of the optic nerve; this is the blind spot of the eye. The text-book gives directions for demonstrating the presence of this spot.

11. **Blood-Vessels of the Eye.** Often the blood-vessels of the eye may be seen radiating from the blind spot, over the inner surface of the choroid, showing after the retina has been washed away. These vessels are branches of an artery which enters the eye with the optic nerve.

12. **Attachment of the Iris.** Examine the anterior portion which was removed to demonstrate the vitreous humor. Notice how the iris is attached at the point of union of the cornea with the sclerotic.

13. **The Lens.** Study the position of the lens, still held in place. It is surrounded by a membrane. Cut through this membrane and turn the lens out. Notice its transparency and shape.

If the lens is not of the proper curve to bring the rays of light to a focus on the retina, then lenses of glass can be placed before the eye to compensate for the defect, as in long-sighted and short-sighted eyes. If the

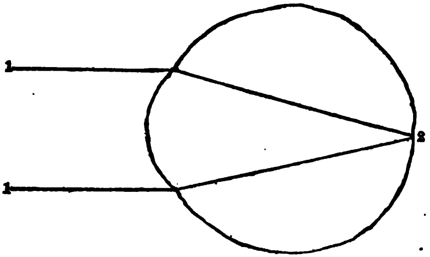

FIG. 32. — Diagram of a normal eye, illustrating that when parallel rays of light (1) enter the eye and are refracted by the lens, they are brought to an exact focus on the retina (2), thus giving distinct vision.

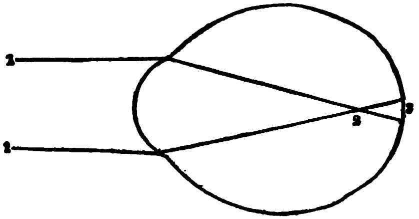

FIG. 33. — Diagram to illustrate near-sightedness: caused by too great length of the antero-posterior diameter of the eyeball, whereby the focus (2) is formed in front of the retina (3), causing a blurred image.

lens becomes opaque, no light can pass through it, and there is blindness, as in cataract. In these cases the lens may be removed, and glasses worn to compensate for the loss.

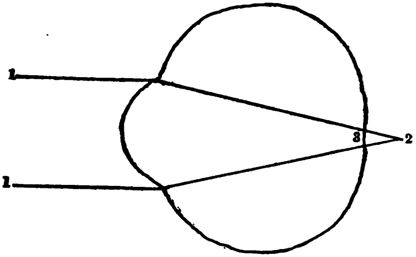

FIG. 34. — Diagram to illustrate long-sightedness: caused by too short antero-posterior diameter, whereby the focus (2) is formed back of the retina (3), thus causing a blurred image.

CHAPTER X.

TASTE. — TOUCH.[1]

1. **Moisture Necessary to Taste.** (*Materials: Sugar, salt.*) Wipe the tongue dry. Drop on it a few grains of sugar; there is no taste. Allow the saliva to dissolve the sugar, and the sweet taste is quickly detected. Try this experiment with common salt; the result will be the same.

2. **Confusion of Taste and Smell.** (*Materials: Potato, apple, onion, all cooked or uncooked.*) Pinch the nose tightly, and breathe through the mouth; close the eyes. By so doing the sense of smell is cut off, and the eyes cannot aid the sense of taste in detecting the different substances.

Place on the tongue a small amount of any of the following: potato, apple, or onion. These should be as nearly of the same consistency as possible, and all cooked or uncooked. It is often impossible to tell which one of the three is in the mouth.

3. **Acuteness of Taste.** (*Materials: Sugar, quinine.*) Place a small crystal or a few granules of sugar on the front of the tongue, and at the same time an equal quantity on the back of the tongue. Notice which has the

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[1] The Essentials of Health; A Healthy Body; A Primer of Health.

more marked taste. Sweets are usually tasted most acutely at the tip of the tongue.

Repeat the experiment, substituting quinine for the sugar. The bitter will be most marked at the base of the tongue.

4. **Impressions of Taste remain.** (*Materials: Peppermint candy, quinine.*) Place a piece of strong peppermint candy in the mouth. When well dissolved, swallow it, and immediately place a minute amount of quinine in the mouth. It will scarcely be tasted. Wash down the quinine with a swallow of water, and notice that the taste of the peppermint is still the more marked of the two. Try other substances than quinine.

5. **Touch. — Relative Sensitiveness.** Use a pair of small compasses, and separate the points a considerable distance. Have the person experimented upon close the eyes. Touch the back of the hand with the two points at the same time. Ask how many points were used, — one or two. Then bring the points nearer together and try again, repeating the question. When the points are well separated, the person answers correctly that two points touch the skin; but when the points come quite close together, they feel as one point, and the question is so answered.

Note how near the points are together when they feel as one point. Let this represent the degree of sensitiveness of that part. Then try the experiment on the tip of the finger, palm of the hand, cheeks, and forehead, and note the relative sensitiveness of the parts, as compared with the back of the hand.

6. **Sense of Weight.** Test the difference in weight of two bodies by holding one in each hand; or by lifting

one and then the other, using the same hand. Use small objects, as coins, to test this sense. Notice how slight differences may in this way be readily detected.

7. **Sense of Pressure.** Place the hands flat on the table, with the palms up. Put weights on them; determine the differences in the weight of bodies by the pressure they exert on the hands, bearing in mind that the hands must be held flat on the table. It is easily demonstrated that this sense is not so delicate as the sense of weight.

8. **Delusions in Weights.** Have two equal weights, one warm and the other cold. Ask a pupil to test which is the heavier, using the sense of weight and also the sense of pressure. The cold weight will be declared to be the heavier.

9. **Tests of Different Senses.** Let the pupil place one hand behind him, and determine with that hand as much as he can regarding various objects that are placed in it. Have the class record the results of the experiment. In a similar way discover what can be determined by each of the special senses in turn, taking care to isolate, so far as possible, the action of the one in question from any of the other senses.

CHAPTER XI.

EXPERIMENTS WITH ALCOHOL.—VIVISECTION.

THE great object of teaching the effects of alcoholic drinks on the human system is to prevent the use, as a beverage, of any liquid which contains alcohol.

No experiments can be performed with alcohol or its compounds unless the liquors are purchased. To be sure, the purchase and the experiments might be made by the teacher alone. To recommend this, however, is to oppose modern methods of instruction, which demand that the pupil be required to do as much for himself as possible. This being the case, a few serious questions arise.

Questions. Shall the pupil procure the necessary material for these experiments, and shall he be allowed to make these experiments? Granting that the teacher can procure the supply and make all the experiments, will this work be confined to the school-room? If a boy is urged by his teacher to dissect the eye of an ox in his room, how can she consistently forbid his experimenting with alcohol there, also, provided she has done the work before him in the school-room? Can it be assumed for a moment that a boy, or a company of boys, would experiment with intoxicating drinks outside the school-room without at least undergoing a strong temptation to taste these drinks? Has a teacher the right thus to place temptation before a pupil? In a word, will not experiments with alcohol in the school-room lead to the repetition of these experiments by the pupil in his room?

Touching, then Tasting. Human nature is such that should the teacher caution the pupils against this work at their homes, a strong desire would be awakened in many cases to undertake the work. It is taught that alcohol is a poison, and it is hardly consistent to place an agent with such power for evil within the reach of our boys and girls. The inconsistency is even more marked when all our endeavors are directed toward keeping our boys from becoming in the least familiar with this destructive agent, as touching is so often followed by tasting.

Other Objections to Experiments. But there are other objections to recommending experiments with alcohol. Distillation and vaporization properly belong to physics, and their demonstration here is out of place. That alcohol is made, and that it exists in beer and wine, demands no more demonstration than the fact that it intoxicates. There are many problems in physiology which must be accepted by the student without demonstration. Some of the "startling experiments" with alcohol and egg-albumen, as demonstrated occasionally on the lecture platform, are illogical and damaging to the cause of temperance. Because alcohol hardens a piece of liver in a few days when kept in a dish, is no reason why an alcoholic beverage will change the liver of a man who takes it into a substance as hard as stone, and all within a week! Because a mixture of pure alcohol and blood in a test-tube causes the blood corpuscles to be destroyed is no reason for concluding that a dose or many doses of whiskey, or even brandy, will destroy a man's blood. The bright student knows that the body could not live without its blood corpuscles; and he further knows that these could be but little affected without causing death. He knows that strong alcoholic drinks do not harden all the albuminous tissues in the body, as the test-tube would lead him to conclude; otherwise some old inebriate whom he knows would have died long ago. The truth against alcohol is strong enough; let us be careful how we teach it.

Conclusion. The conclusion of the matter is this: To place alcoholic drinks within the reach of any pupil, or to open the way whereby there can be any excuse for his handling or tasting the same, is to commit an act which cannot be too strongly censured. To demonstrate its mode of origin and its presence in mixtures is unnecessary; and to illustrate its action on dead tissues and draw conclusions therefrom, is often to mislead the pupil and raise grave questions of doubt in his mind. Experimenting with alcohol has no place in our public schools.

Vivisection. There is no good and sufficient reason why vivisection should be employed, as a method of illustrating physiological truths, in the public schools. However great a debt science may owe experimentation on living animals, — however much this may have contributed to our present knowledge of the prevention, treatment, and cure of disease, — it is evident that the public school is not the place for this kind of study.

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CHAPTER XII.

HOW TO USE THE MICROSCOPE.

Importance of Microscopic Work. It is of practical value to know that a poached egg is more easily digested than roast pork. It is interesting to learn that the albuminous foods are digested in the stomach by the gastric juice. It is proceeding a step further to know that this juice is secreted by the gastric glands. It is entering still deeper to learn that these glands are composed of cells, and that each cell is a laboratory, manufacturing its share of the digestive fluid.

The microscope brings us to the grand climax of our study. By its aid we can look upon these cells, and thus be brought to the very door of the unsolved secrets of life.

Again, it is impossible to comprehend the vast number of red corpuscles in a minute drop of blood, simply from reading a statement in the text-book. It is equally impossible to understand their great function as oxygen carriers. When, however, the eye beholds the countless numbers of these minute bodies, as revealed by the microscope, new light is suddenly thrown upon the whole study.

Recognizing the great value and importance of well-directed microscopic work in connection with instruction in physiology, the author here presents a line of simple experiments with the microscope. These experiments are illustrative of the text-book work fully within the comprehension of pupils, and not too complicated to be performed by the teacher who is unfamiliar with microscopic work. Provision has also been made for a suitable microscopic outfit obtainable at a moderate cost. The Health Series Microscope with outfit affords an instrument of maximum excellence at a minimum price. Full announcement of this microscope, with a complete description, price, etc., will be found on page 95.

Difficulties. The author understands something of the difficulties which surround the teacher in taking up this branch of study. Yet with the aid of the simple directions given below, he believes any teacher can intelligently and profitably use the microscope in class work.

Two Kinds of Microscopes. Microscopes may be divided into two general classes, simple and compound.

With the simple microscope the object is viewed directly; that is, the magnified image of the object passes at once to the eye of the observer. With the compound microscope the image formed by the simple microscope is again magnified before it passes to the eye.

A single magnifying-lens, as a pocket magnifier, is an illustration of the simple microscope. The compound microscope requires at least two lenses, one of which will magnify the image formed by the other lens.

Image Reversed. When an object is magnified with the simple microscope, it appears in its true position but the compound microscope gives an inverted image. As a result, when the object that is being examined is moved to the right it appears to the observer to be moved to the left. Soon, however, one becomes familiar with this reversed order of things, and is not in the least annoyed by it.

Magnifying Power. Microscopes are said to have a certain magnifying power, as 100 or 500 diameters. This is generally written ×100 or ×500.

It is evident that lenses magnify the object equally in all directions, hence the *area* is increased an amount equal to the square of the *linear;* that is, if the object be magnified five *diameters* (*linear*), it is increased twenty-five *times* in area. Only the magnifying power in diameters is given.

The Objective. The objective is the magnifying-glass which is placed nearest the object to be examined. Upon its perfection largely depends the distinctness of the image. A microscope may be very handsome, large, and expensive, yet if it is not furnished with an objective of a high order of workmanship it is practically without value.

How Objectives are Numbered. Objectives are numbered according to their equivalent focal lengths. For instance, with the Health Series Microscope there are $\frac{2}{3}$ and $\frac{1}{6}$ inch objectives. These figures denote that each objective has a magnifying power equivalent to the magnifying power of a simple lens whose focal distance is represented by that figure. Thus, a $\frac{1}{6}$ inch objective magnifies the same as a simple lens having a focal distance of $\frac{1}{6}$ of an inch.

Construction of Objectives. An objective is made of more than one lens, because when only one is used (higher than a certain magnifying power) the object is seen fringed with color and the image appears distorted. These defects are known as chromatic and spherical aberrations. To correct the aberrations it is necessary to use two kinds of glass, flint and crown.

Two objectives may have the same magnifying-power, and yet one may cost many times more than the other, because of the greater freedom from these aberrations. An expensive objective is often composed of four or six lenses. A good objective should give a clear, distinct, and sharp outline to the image, and should enable the observer to detect delicate structure.

Working Distance. The working distance is the space between the front glass of the objective and the point in focus. As the objectives increase in magnifying power they are nearer the object when in focus. Hence the $\frac{1}{6}$ inch objective is in focus much nearer the specimen than the $\frac{2}{3}$ inch.

The Eye-Piece. The eye-piece is the magnifying-glass which is placed nearest the eye. It is usually composed of two lenses. It magnifies the image formed by the objective. Eye-pieces are made of different magnifying power.

The Field. By the field is understood all the circle of light presented to the eye through the microscope.

Light. Direct sunlight should never be used. A north light is generally preferable; hence, when possible, it is best to place the instrument on a table near a north window.

To begin Work. Draw the instrument from the case by grasping the base. Incline the instrument by placing the left hand upon the base, and the first two fingers of the right hand around the arm just above the stage, when a slight pull with the right hand will move the instrument to any desired angle.

Incline the microscope to a position which is as comfortable as possible for the observer when seated for work. Inclined in this way, the student's neck is not strained nor the chest compressed.

Diaphragm. See that the large opening in the diaphragm, which is just beneath the stage, is directly opposite the opening in the stage itself.

Placing Eye-Piece. Place the eye-piece in the tube, being careful not to use force enough to push down the body of the instrument. Do not introduce or withdraw the eye-piece with a spiral or twisting motion, as this is likely to scratch or mar the finish.

Objective. Raise the body of the microscope by turning the large milled heads, the coarse adjustment.

Remove the $\frac{3}{8}$ objective from the case and attach it to the lower part of the body. Be careful that it does not drop from the fingers.

Do not touch the front lens with the fingers, as they leave a mark which must be removed before the specimen will show to good advantage.

Mirror. Have the mirror bar in a direct line with the body of the microscope.

Preparing Specimens. Clean one of the glass slides with soft linen or chamois. Place on it a small clipping from the end of a feather, or a piece of thin cotton cloth not more than $\frac{1}{4}$ of an inch square. Place on the specimen a small drop of clean water. Pick up one of the thin glass covers and look through it to see if it is clear. If not, breathe on both sides of it and wipe with the soft linen.

Great care is necessary in cleaning these thin glasses, for they are easily broken. The thin glass may be grasped by its edges between the thumb and index finger, and with the piece of linen placed between the thumb and index finger of the other hand the surfaces may be rubbed clean. If any uneven strain be placed on the glass, it will quite surely be broken.

Place one edge of this cover-glass on the glass slide, catch the opposite edge on the point of a pencil, and let it fall gently and directly over the specimen. With the pencil make slight pressure upon it, to press out any excess of water, and also to flatten the specimen. Remove any excess of water from the surface of the cover-glass or from around its edges with small pieces of blotting-paper.

Not a particle of water, or other re-agent of any kind, should ever be allowed to come in contact with the objective.

Place the preparation on the stage of the microscope and have the specimen directly over the central opening.

Again place the hand on the mirror and move it until the light is seen reflected on the specimen. It only remains now to focus the instrument.

How to Focus. Incline the head until one eye is on a level with the stage. With the hand on the coarse adjustment, lower the objective until it nearly touches the cover-glass.

One thing now is certain: the objective is *too near* the specimen. Therefore, when the eye is placed at the top of the instrument, the objective can always be moved *frôm* the specimen, not towards it. Simple as this seems, yet few apparently understand it. Its strict observance will prevent the destruction of a large number of specimens, and save many objectives from injury.

Place the eye just above (close to) the eye-piece, and if the field is dark, move the mirror slightly until the light is so reflected that the field is brighter.

With the hand on the coarse adjustment, and with the eye still in position, slowly *raise* the objective. Gradually the image will appear, becoming more and more distinct. When the point of most acute vision is reached, the object will then be in focus.

The Fine Adjustment. The coarse adjustment is sensitive enough for the $\frac{2}{3}$ inch objective, but when the $\frac{1}{6}$ is used the fine adjustment is necessary.

After focusing as correctly as possible with the coarse adjustment, place the thumb and first finger on the fine adjustment, and move it slowly toward the right or left, back and forth, until the specimen is seen to the best advantage.

If the fine adjustment does not make any impression, it is probably because it is "run out." The screw has come to its stop. It is only necessary to turn the milled head a number of times, either one way or the other, to bring it into action.

The Inverted Image. With the $\frac{2}{3}$ inch objective and the specimen prepared as above, become as familiar with the workings of the instrument as possible. Move the specimen in various directions in order to become familiar with the inverted image. With the hand on the mirror experiment with the light. Try the plain side of the mirror.

Carefully pull out the draw-tube until the mark on the tube just comes in sight. Re-focus the instrument, and notice that the magnifying power has been increased. For all future work use the draw-tube thus extended.

The $\frac{1}{6}$ Objective. For this high power a more careful arrangement of the light and a more correct adjustment are necessary.

It is more difficult to prevent the end of the objective from being soiled or moistened with water when specimens are examined. Pieces of blotting-paper should always be at hand to remove any excess of water from the top or from around the edges of the cover-glass. If the objective becomes moistened or soiled, it should be made clean by wiping it carefully with the soft linen or with a clean chamois before attempting its use.

Dust on the Eye-Piece. If black specks are seen when looking in the microscope, it is possible they are on the eye-piece. This is easily ascertained by turning the eye-piece while looking through the microscope. If the particles of dust turn with the eye-piece, then they must belong to it.

Brush the upper surface of the glass with a camel's hair brush. If the specks still remain, remove the eye-piece and unscrew the lower glass from it. Brush the upper surface of this glass with the camel's hair brush and replace.

Staining. Most soft tissues show but little of their structure if examined in thin sections without previous treatment. In order to bring out the individual parts it is necessary to stain the sections.

It so happens that the different parts of a tissue take certain stains in varying degrees. It is true that one tissue will take a stain while another one will be unaffected by it. It is also a fact that the nuclei of cells will take staining more intensely than other parts.

All tissues, with the exception of bone and teeth, are generally stained before they are examined. In the specimens which accompany the Health Series Microscope the effects of these stains are very evident.

Other Preparation Necessary. Nearly all the tissues have to undergo treatment prior to the staining. To procure thin sections of such tissues as the stomach, kidney, liver, or spinal cord, it is necessary to harden them, after which they must be firmly imbedded in some medium which will hold them in place while thin sections are cut with a knife or razor.

The sections must then be stained and subjected to other treatment before they are in a condition for permanent preservation on the glass slide. These various steps are surrounded with such difficulty that one who desires to become skilled in this direction must consult text-books on the subject. A valuable work for this purpose is Stirling's "Histology."[1] This is the companion volume to the "Practical Physiology" already recommended. From the catalogues of publishers may be obtained the titles of other works on histology and microscopy.

[1] Published by P. Blakiston, Son, & Co., Philadelphia.

CHAPTER XIII.

EXPERIMENTS WITH THE MICROSCOPE.

Miscellaneous Specimens. Let the first lesson be devoted to the examination of a number of interesting specimens.

Small clippings from a feather, fibres of cotton, linen, silk, or wool, scales from the wings of butterflies, or moths, — all form interesting specimens for examination with each objective.

Place one of the above specimens on the centre of a glass slide, add a small drop of water, and cover with a thin glass. Press lightly on the glass with the end of a pencil, and remove any excess of water with pieces of blotting-paper. Examine first with the ⅔ and then with the ⅙ objective. The former is called the "low," and the latter the "high" power.

Cells. ("The Essentials of Health," Chapter I. Plate 1, Fig. 5; "A Healthy Body," Chapter on Cells.)

With the blade of an ordinary pocket-knife carefully scrape the inner surface of the cheek. Place the scrapings on a glass slide, and mix with them a small drop of ordinary red ink. Cover with the thin glass, press lightly, and remove any excess of liquid from the edges.

Examine first with the ⅔ objective. The cells are scarcely visible with this magnifying power. Examine with the ⅙ objective. Move the specimen about until there are in the field a few cells which correspond fairly well with the illustration on the plate. The nucleus will be seen as a minute round body in the centre of each cell, more deeply stained than the other parts.

Fat. ("The Essentials of Health," Chapter III. page 24, Fig. 23; "A Healthy Body," pages 68, 69.)

Place a small drop of fresh milk on the glass slide, cover, press slightly, remove excess around edges, and examine with the ⅙ objective. The minute bodies are the fat globules of the milk.

Prepare a small drop of skimmed milk in the same way. Notice the absence of nearly all the fat globules. If all the cream had been removed, no globules would be present, but a few are generally found.

Place a small drop of cream on the slide, and mix with it an equal quantity of water. Cover with the thin glass, gently press on the cover, remove excess from edges, and examine with the high power (the ⅙). It will have all the appearance of fresh milk.

Starch. ("The Essentials of Health," Chapter IV. Figs. 4, 6, and 7; "A Healthy Body," Chapter on Cells.)

Place a small amount of wheat flour (not larger than one-fourth the size of a mustard seed) on a glass slide; add a small drop of water, mix, cover, remove excess from edges, and examine first with the low and then with the high power. Prepare a similar slide of cornstarch.

After removing a slide from the microscope, place at one edge of the cover-glass a small drop of the iodine mixture described on page 18. At the opposite edge of the cover place a piece of blotting-paper. The paper will absorb the water near it, and thus draw under the iodine mixture from the opposite edge. Remove any excess of the iodine solution with the blotting-paper, and examine with the high power. One part of the preparation will contain the starch as first seen, while the other part will show the effect of the iodine. This is the surest test for the presence of starch.

With the blade of a knife gently scrape the fresh cut surface of a potato. Place a small amount of the scrapings on a glass slide, add a minute quantity of water, and mix. Then add a minute drop of the iodine solution. Cover with the thin glass, press lightly, remove all excess of the mixture, and examine with the low power. Portions of the preparation will look blue, showing the effect of iodine on the starch. Other portions will have only a slight yellow color, due to the action of the iodine on the framework or cellulose of the potato.

Teeth. — Saliva. ("The Essentials of Health," Chapter VII. Figs. 13 and 14; "A Healthy Body," Chapter XII. Fig. 22.)

Place the prepared section of a tooth under the microscope, and study first with the low power and then with the $\frac{1}{6}$ objective. The high power will show the fine canals of the dentine, and also the peculiar structure of the cement.

Place a small drop of saliva on the slide, add a minute drop of red ink, mix, cover, press gently, remove any excess of liquid, and examine with the high power.

This preparation will show the same kind of cells as those obtained from scraping the inner surface of the cheek, although not in such abundance. By moving the specimen views will be obtained of the lymph corpuscles. It is well to remember that these appear like the white blood corpuscles.

Section of Stomach. ("The Essentials of Health," Chapter VIII. Figs. 16 and 17; "A Healthy Body," Chapter XIII. Figs. 26 and 27.)

Examine with the low power the prepared section of stomach.[1] It is possible to obtain a view showing something like Fig. 16 in "The Essentials of Health." The individual glands, however, will not show so clearly as represented in the illustration.

Examine with the high power. Move the specimen until the cells are seen almost as clearly as represented in Fig. 17 of "The Essentials of Health," or Fig. 26 of "A Healthy Body." The specimen must be carefully moved about until those parts of the glands which correspond to the lower portion of these illustrations are in the field.

Call attention to the fact that these cells have the power of taking material brought to them by the blood and manufacturing from it the secretion known as gastric juice.

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[1] See p. 98.

Section of Liver. ("The Essentials of Health," Chapter VIII. page 76, Fig. 19 A; "A Healthy Body," Chapter XIV.)

Examine with the high power the prepared section of liver. Move it around until a good view of the individual cells is obtained. These will be of the general shape of those represented in Fig. 19 A, "The Essentials of Health," only not so highly magnified. The nuclei in the cells can be clearly seen. The cells are packed so tightly together that there is apparently no room for other tissues, yet between the cells are bile ducts and blood vessels.

These are the cells which are capable of storing up the digested starchy foods and giving them out again as the body demands. They also manufacture the bile.

Scrape the freshly cut surface of a piece of liver procured at the market. Place a minute amount on the glass slide, and mix with a small drop of red ink. Wait a few moments before covering so that the cells may be stained. Then add the cover, slightly press on it, remove any excess from edges, and examine with the high power.

This specimen will show a large number of distorted blood corpuscles, granular matter, and possibly some fat, besides the liver cells. By moving the specimen about, a few liver cells will be found which show clearly.

Section of Intestine. ("The Essentials of Health," Chapter IX. Figs. 20, 21, Plate 2; "A Healthy Body," Chapter XVI. Fig. 31.)

Examine the prepared section of intestine with the low power. Study especially Figs. 21, "The Essentials of Health," and 31 B, "A Healthy Body."

The blood vessels are injected in the prepared specimen furnished with the Health Series Microscopes, and show fairly well. The central lymphatic vessels do not show. They are demonstrated with difficulty.

Examine with the high power, and study the illustration in the text. Only a portion of a single villus can be brought in the field at one time. The network of blood vessels now shows to good advantage, and also the layer of epithelium surrounding the villi.

Interesting specimens can be prepared from the intestine of any recently killed animal. Open the canal longitudinally for a few inches, and gently pour clean water over the mucous membrane. With the blade of a knife carefully scrape the free surface of the lining membrane, and mix a minute quantity of the scrapings with a small drop of red ink. After waiting a few moments for the tissue to stain, cover with the thin glass, gently press, remove any excess, and examine with the high power. Often portions of villi are seen, surrounded with a layer of cells. Individual cells are also seen floating in the field. They are exceedingly minute, even when examined under this high magnifying power. In shape they correspond to those represented on Fig. 1 (1) and (2), "The Essentials of Health."

Blood Corpuscles. ("The Essentials of Health," Chapter X. Figs. 23 and 27; "A Healthy Body," Chapter XVII. Fig. 33.)

To procure a specimen of human blood tie a string tightly around the base of one of the fingers. In a few moments the finger will become dark, because well filled with blood. The string has only prevented the flow of venous blood from the finger, and has not interfered with the flow of arterial blood to it. This is because the veins are near the surface, and the arteries are more deeply seated.

With a needle prick the end of the finger, or thrust the needle through the skin just back of the nail where it is not quite so sensitive. Pressure on the finger will now cause a small drop of blood to exude. This should be no larger than the head of a pin. Place the centre of a glass slide in contact with this small drop; lower the thin glass carefully over the blood and examine with the high power.

Usually the corpuscles are too thick to show well, but by moving the specimen about it is possible to obtain views of the individual cells. The red corpuscles are of a yellow or straw color, and often arranged in rows, as if a number of them were fastened together side by side. By gently tapping the edge of the cover-glass, slightly moving it, these rows are destroyed, and the corpuscles are seen separated from each other.

The white corpuscles are not easily found. They resemble, in many particulars, the lymph corpuscles seen in the saliva. They are very transparent, and few in number.

Another method of preparing the blood is by drawing the glass slide quickly across the drop of blood, and then covering with the thin glass. Some portions of the slide will show the corpuscles in a single layer, where they may be studied to advantage. Few of them, however, are seen on the edge when prepared in this way.

Remember that no re-agent, as water, must be added to either of these preparations. Water dissolves the red corpuscles.

Prepare a specimen by either of the above methods. Add to it a minute drop of red ink. After waiting a few moments add the cover, press lightly, remove excess from edges, and examine with the high power. The white corpuscles will now appear as spherical bodies, slightly stained. Possibly a minute nucleus may be seen in each.

The large, oval, and nucleated red corpuscles can be obtained from the blood of a recently killed fish, fowl, or frog. Place a minute drop on a glass slide, and spread evenly over the central portion of the glass with a needle. Apply the cover with care, and examine with the high power.

Prepare another specimen by adding red ink to the blood. After a few moments cover with the thin glass, press lightly upon it, remove any excess, and examine. A careful preparation of these large corpuscles makes a most beautiful and interesting object. Such a preparation is furnished with the "Health Series Microscope," because it is not always convenient or possible to obtain the blood from the animals just mentioned.

Section of Kidney. ("The Essentials of Health," Chapter XIV. Fig. 47; "A Healthy Body," Chapter XXIII. Fig. 47.)

Examine the preparation of kidney with the low power. Notice the large number of round bodies, two of which are illustrated in Fig. 47, "The Essentials of Health."

Examine with the $\frac{1}{6}$ objective. The round dots are the nuclei of minute cells which line the tubes, two of which are represented in the same illustration.

These bodies and the tubes leading from them take the poisonous ingredients from the blood, as described in "The Essentials of Health," page 153.

Bone.—Cartilage. ("The Essentials of Health," Chapter XV. Fig. 52; "A Healthy Body," Chapter on the Bones.)

Examine the preparation of bone with the low power. Consult Fig. 52, "The Essentials of Health." The circular openings are the Haversian canals which contain the blood vessels of bone.

Examine with the high power. Now the lacunæ and canaliculi show to good advantage. Here they are simply cavities, but in living bone they are filled with living matter, called the bone-cells. Impress the pupil with the fact that in the living body bone is a living tissue, filled with blood vessels and bone-cells.

Examine the preparation of cartilage with the high power.

Procure at the market the end of a long bone which aids in forming a large joint. With a sharp knife or razor shave off a thin section in order to remove the thin membrane covering the cartilage. From this fresh surface cut another section $\frac{1}{4}$ of an inch square. It must be exceedingly thin, or the demonstration will be unsuccessful.

Place a small drop of water on the section, cover, remove excess from edges, and examine with the high power. If the section is sufficiently thin, it will be possible to see the minute cells which compose its substance, especially if it is moved until the edge is in the field.

Muscle. ("The Essentials of Health," Chapter XVII. Figs. 71, 72, and 74; "A Healthy Body," Chapter VIII. Figs. 15 and 16.)

Examine the preparation of striated or voluntary muscle with the high power. The individual fibres may be seen with their transverse markings. The nuclei are also seen scattered over the surface of the fibres.

Take a shred of lean meat, as round steak, about ¼ of an inch long, and not larger in diameter than an ordinary pin. Place it on a glass slide and add a small drop of water.

With two needles carefully separate the shred longitudinally until it is divided into a number of pieces. Examine with the high power. The markings on the fibres will often show fairly well, clearly enough for one to decide the character of the structure.

Prepare another specimen in a similar manner, only use lean meat after it has been boiled. The boiling hardens the fibres and softens the connective tissue. As a result, with the aid of the needles, the fibres can be separated much more easily.

Examine the preparation of involuntary muscle with the high power. The cells are seen to be separated as represented in Fig. 74, "The Essentials of Health," and Fig. 16, "A Healthy Body." In preparing such specimens the involuntary muscle was subjected to reagents which dissolved the cement that held the cells together.

Section of Scalp. ("The Essentials of Health," Chapter XIX. Figs. 31, 83, 84, 86, 87, 88; "A Healthy Body," Chapter XXIV. Figs. 48, 50, 51, 52.)

Examine the preparation of scalp with the low power. The hair follicles with their hair shafts show to good advantage. It is possible to see bundles of adipose tissue as illustrated in the lower part of Fig. 83, "The Essentials of Health," and Fig. 48, "A Healthy Body." The sebaceous glands may be seen also.

An examination of this specimen with the high power will show the fat cells as illustrated in the text-books. The hair shafts in their sheaths also show clearly. The hair shaft shows the peculiar markings on its surface, as illustrated in Fig. 86, "The Essentials of Health." This specimen will probably not show the sweat glands, although often portions of these glands may be seen.

Break from a single human hair a piece less than ½ inch in length, place it on the slide, add water, cover, remove excess, and examine with the high power. Prepare a similar specimen of the hair of a cat.

This lesson can be made very interesting by examining pieces of hair from various animals and comparing them, also by examining the hair from different kinds of fur.

Spinal Cord. ("The Essentials of Health," Chapter XXV. Figs. 97 and 98; "A Healthy Body," Chapter XXVI. Fig. 60.)

Examine the preparation of the spinal cord with the unaided eye. Compare the general outline with Fig. 98, "The Essentials of Health," omitting the nerve roots at the right. Notice the central opening; especially notice the central portion which slightly resembles the capital H.

Examine with the low power. Then study with the high power and move the specimen around until the white substance (all of the section not included in the capital H) is in the field. Notice how the nerve fibres appear when cut transversely, and consult the paragraph beneath Fig. 97, "The Essentials of Health."

Move the specimen until one of the points of the letter H, the point which corresponds to the upper portion in Figs. 87 and 88, is in the field. By careful search it is possible to see here the large nerve cells, some forms of which are represented in Fig. 90, "The Essentials of Health." The nuclei of these cells show the effects of staining remarkably well.

CHAPTER XIV.

THE HEALTH SERIES MICROSCOPE.

The Microscope a Necessity. No instructor would think of teaching mathematics without the use of the blackboard and crayon, or paper and pencil. It certainly would be impossible to understand chemistry without the test-tube and re-agents. The day is approaching when the teacher of physiology will realize that this study cannot be successfully presented to more advanced pupils without the use of the microscope.

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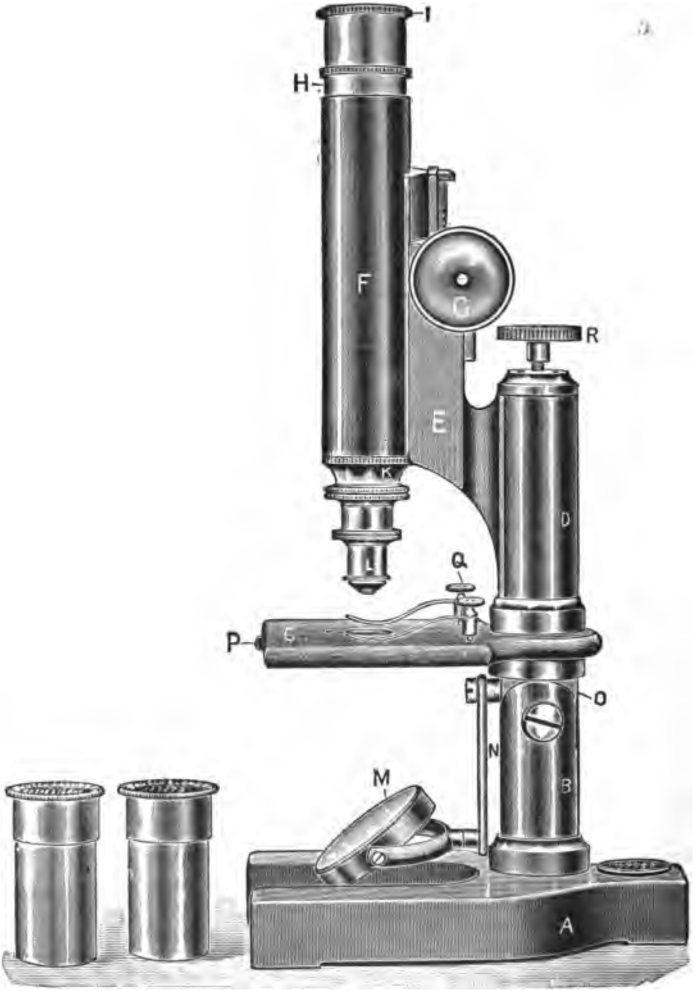

THE HEALTH SERIES MICROSCOPE.

delicate instruments manufactured in the country are made by this company. The author's acquaintance with their instruments dates back over twenty years, during which time they have always been found to give the highest satisfaction.

Detailed Description. The base (A) is of solid metal, japanned in black, and of proper size to render the instrument stable whether used in the vertical or inclined position.

All other parts are of highly finished brass, except the stage (C), which is of oxidized brass to prevent discoloration from contact with re-agents.

The pillar (B) is fastened to the base below, and carries upon its upper end the joint or axis (O).

The arm (D) supports the working parts of the instrument. It is connected with the pillar by the joint, which serves to incline the body.

The coarse adjustment (E) is made by a diagonal rack-and-pinion, moved by the milled head (G), and is of such delicate construction that the $\frac{2}{3}$ objective may be perfectly focused by it alone.

The body (F) is the tube-portion to which the optical parts are attached.

The draw-tube (H) moves in the body and receives the eye-piece (I). It increases or diminishes the distance between the eye-piece and the objective, and therefore either increases or diminishes the magnifying power of the microscope.

At the lower part of the body is a screw (K) of a standard size, in order that any objective of any first-class manufacturer may be used with this instrument.

The objective (L) is so called because it is nearest the object to be examined. It is the most important part of the microscope, for upon its perfection the distinctness of the image, and therefore the value of the instrument, largely depends.

The mirror (M) is provided with plain and concave surfaces. The former is used when but little light is necessary, and the latter when the light must be concentrated upon the object.

The mirror bar (N) allows the mirror to be placed at any obliquity below the stage.

The diaphragm (P) is a perforated revolving disc attached directly beneath the stage. The different-sized openings regulate the amount of light from the mirror.

There are two clips (Q) which are attached to the upper surface of the stage for holding the object in place.

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